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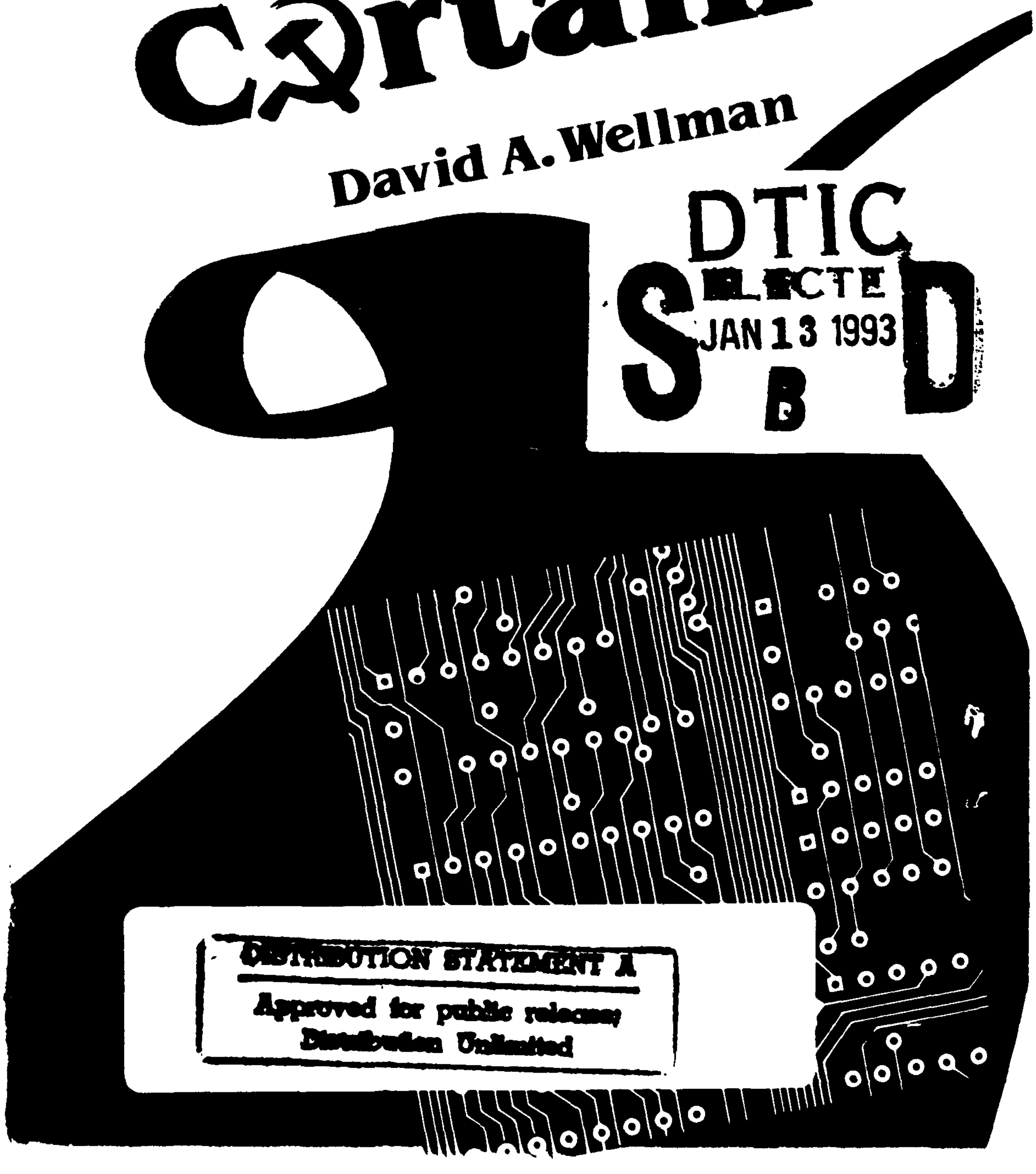
A Chip in the Curtain

David A. Wellman



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COMPUTER TECHNOLOGY
IN THE SOVIET UNION

David A. Wellman

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For Matthew, Kevin, Andrew, and Stephen

Contents

Illustrations

Foreword

THE SOVIET UNION is experiencing an avalanche of social, political, economic, and perhaps ideological change. President and General Secretary Mikhail Gorbachev, with the apparent support of the Soviet leadership and people, has begun a number of major reforms. No doubt influencing—if not driving—this change is the unparalleled technological progress of the West, which the Soviet system yearns for but has been unable to match.

Focusing on computers as a leading indicator of technological progress, *A Chip in the Curtain* explains the Soviet Union's struggle with the development and, more important, the application of computers in Soviet society. Without question, the USSR's track record with computers compares poorly to that of the West and contributes to Soviet technical and economic woes. Author David Wellman shows how a continued Soviet lag in this area is the trend of the future.

President Bush, during his election campaign, suggested that the Iron Curtain is rusting—imagery both picturesque and telling. Depicting a part of the Soviet problem, this book presents a clear picture of a real and growing erosion of the world's most formidable barrier. Few events would have a more pervasive impact on the course of the next century than the opening up of the Soviet system and society. This book tells us much

Photographs

Tables

Acknowledgments

I WISH TO EXPRESS my sincere appreciation for the help freely and gladly given to me throughout the process of preparing this book. Chief among my supporters and believers were my wife, Debora, Carl Hammer, Fred Kiley, Janis Hietala, Donald Anderson, Joseph Goldberg, Michael Woods, Edwin Carlisle, Roger Lewis, James Gaston, Nancy Jemiola, and Fred Boli.

about one factor—chronic Soviet weakness in computers—which is impelling Soviet leaders in that desirable direction.

BRADLEY C. HOSMER
Lieutenant General, US Air Force
President, National Defense University

Preface

WHY SHOULD WE BE CONCERNED with the USSR and its use of computer technology? For me the story begins more than 10 years ago. As a student at the Amphibious Warfare School in Quantico, Virginia, like my classmates, I pursued detailed knowledge of the force structure, equipment, and warfighting doctrine of my Service, the US Marine Corps. At some point in that course of instruction, it was suggested that, as we competed for grades on tests and strove for the most concise and clever operations order to defeat a fictitious enemy, we reflect on the real and ultimate competition that we were preparing ourselves for. That competition, which we hoped we would never have to engage in, would be against a real enemy in a life or death situation. In other words, to study material that related to the principal adversary of our nation made good sense: know the adversary's force structure, doctrine, and equipment. And, to carry the concept one step further, get inside the mind and decisionmaking process of that adversary in order to better understand points of difference that can lead to conflict. This made a great deal of sense at the time, and still does.

So I came to be motivated to begin devoting my discretionary time to the study of the USSR. This is not to suggest that I anticipate imminent hostilities with the Soviet Union. However, with our nation and the USSR

at loggerheads over many issues in the world, the Soviets do represent, either directly or through surrogates, the principal political and military threat to our nation in the world today. Finally, as my most recent formal education and my secondary occupational specialty in the Marine Corps are in the area of information systems technology, to combine the two interests seemed a natural and efficient use of time and energy.

However, the convenient use of acquired knowledge and skills was not the prime motivator in my research. Computer technology plays a key role in contemporary technological competition between the US and the USSR. The ability of each nation—each system and each culture—to develop and use computer technology will be a major factor in the outcome of superpower competition. Simply put, this is an important topic.

What follows here is a continuation of this independent research, pursued while I was a student and Senior Fellow at National Defense University.

A Chip in the Curtain

1. The Issue

GALINA V., an elite Soviet computer scientist, uses a Japanese-manufactured IBM PC/AT clone. Her computer is connected via a dedicated line to her research laboratory at Zelenograd, the Silicon Valley of the Soviet Union. Galina can access only five separate research data bases with her home computer and is not allowed a printer at her home. All printers at the research laboratory are remotely accessed via the laboratory's computer network and kept under special security. Output from these printers is carefully controlled by the laboratory's administrative staff.

Vladimir R., a well-to-do resident of Moscow, is a Slavic-to-Russian translator for economic and sociological articles appearing in publications from Eastern Europe. An informed individual, Vladimir would like to spend a few thousand rubles from his savings for a personal computer. After months of being directed from office to office throughout the city, he has abandoned his quest. Although such devices are said to be in production, a policy for their sale and use has not yet been developed. Besides, such scarce state resources are needed at vocational training centers.

Sergei K. is a student in one of the eight newly organized and equipped "informatika" (information science) vocational training centers in Moscow. The byword of all his training is "the office computer kollektiv," a Soviet concept of the organization and use

of computer technology. The computer devices Sergei uses are frequently being repaired. He must take careful notes from the instructors concerning the operation of the system he is being trained to use; there is no printed textbook for this particular system. When Sergei or his fellow students make mistakes, the instructor frequently is at a loss to explain the situation or unable to recover from the error. Thus, the class wastes time retracing events to the point of the failure and attempting a different transaction or response at the troublesome juncture before it can proceed.

Boris M. is the senior manager for production in a plastics plant in the Ukraine. He is well-attuned to what makes the system work when it comes to turning out plastic inserts for cabinets and office furniture. Boris is discreet in his methods for reporting 12 percent of the raw materials which come to his plant as unusable in his production process. Over time, he has found a way to blame this shortcoming primarily on failure to follow proper procedures during the shipment of the raw materials to his plant. Because it is uneconomical to return the "useless" materials, Boris has been able to create an emergency stockpile of supplies. This arrangement provides a pool of materials that the plant's workers can use to fabricate raincoats and shopping bags, which sell well on the streets of Moscow. Although Boris is adept at creating a sea of paper work to "hide" the "useless stocks" and using his "contacts" to subvert inquiries into the situation, he fears the rumors of a computer-based system that would create an audit trail capable of profiling the "useless" raw materials that seem to vanish into thin air. He will actively work to avoid the use of such a system in his plastics plant.

Thesis for Thought

Fictional accounts? Yes but nonetheless indicative of the status of computer usage inside the USSR. However, I will not resort to fiction in the remainder of this work; though much of what is revealed may seem bizarre, it is all factual. This is a study of friction, a real and powerful friction at work in a real and powerful country. The abrasion is between today's most dynamic technology—computer technology—and the rigid and confining structure of Soviet communism, and the importance of this turn of events is a function of the increasing dominance of the technology of the computer—a technology present in an ever-growing number of products and processes. A major cause of this friction is the political and social conservatism of the Union of Soviet Socialist Republics. This authoritarian regime is challenged by computer technology. Compared to the other leading industrial nations in the world, the USSR has not been able to fully absorb and exploit the capabilities of the computer. I titled this book *A Chip in the Curtain* for a special reason. Let the word "chip" stand for computer technology as a whole, and Winston Churchill's "Iron Curtain" as a symbol of Soviet tyranny—in this sense the chip is a powerful contemporary force working to erode the viability of the Iron Curtain.

Just as one does not need to know in detail the functioning of the internal combustion engine to operate an automobile, nor be an accomplished musician to appreciate the works of Mozart, we do not need to be computer scientists to understand the issues confronting the USSR in its struggle to effectively accommodate computer technology. The layman need not fear that this text is a discussion of the intricacies of IBM's latest 32-bit microprocessor as it compares with the

Soviet 16-bit K581/K536 computer chip. However, from the characteristics and uses of these and a host of related computer devices flow information processing charcteristics that markedly affect the future of the USSR in a world oriented increasingly toward information.

Soviet military and space programs are not entirely exempt from this assessment. These programs, the principal basis for the Soviet's superpower status, are normally shrouded in secrecy. But even in these areas—in national defense and in the exploration of space—as in education and industry, the Soviet leadership would welcome access to more capable Western computer technology.[1] Up to now the Soviets have been able to match the West in military technology and in selected scientific pursuits, only by applying an all-out effort to a specialized project. In the immediate future, we may expect the USSR to continue to spare neither material nor manpower assets to maintain its superpower status. However, given the pace at which computer technology is advancing, an inability to effectively assimilate this technology in Soviet society may well threaten the viability of the USSR's status as a superpower. And, although difficulties in the USSR in defense and space will be largely matters of shortages of sophisticated hardware, the absence of computer technology in other areas of Soviet society is more difficult to explain.

The Soviets have applied computer power in military and space programs with some success but lag in the "civilian" sector, i.e., education, health care, industry, and business. Up to date use of computer technology, readily available in the West, is extremely limited in these areas. Those of us who see the proliferation of computers in every facet of society—in government, military, business, and public services as well as in private use—cannot comprehend how a major world

power like the USSR can function effectively without making more extensive use of modern computer technology. Although the Soviets are currently weak in the everyday application of computer power (a serious problem), even greater problems resulting from this weakness lie in the near future. As the pace of computer applications accelerates in the industrial countries of the West—as it does each year—the USSR will fall further and further behind in its goal of reviving a sluggish national economy and maintaining its prestige in the eyes of the world.

Soviet Concern

The Soviet leadership acknowledges this situation and predicament. General Secretary Gorbachev, when speaking about the party's policy of renewal and restructuring, consistently and repeatedly calls for more "dynamism and creativity, better organization and order, more scientific and enterprising approaches in the economy, and more efficient management practices."[2] In such calls for change, Gorbachev invariably singles out computer technology as an object of special attention. His close advisers do likewise. Yevgeniy P. Velikhov, Soviet academician, Vice President of the USSR Academy of Sciences, and founder in 1983 of the Department of Informatics, Computer Technology, and Automation, frequently speaks out on this subject. During a Moscow Television Service interview on 22 March 1984, Velikhov stated,

> We [the USSR] are currently in transition, where a real revolution is occurring in the sphere of information science and computer technology. It is still occurring, and it has not finished.
>
> The revolution is related to the fact that we are changing [and the world is changing] from the production of single

computers . . . numbered in the thousands or tens of thousands, to millions and tens of millions. In other words, computer technology is truly becoming a mass thing.

The question of so-called computer literacy arises. It is taking its place alongside grammatical literacy, if you will. Generally, computer technology and information science has won its place in science. Naturally, it is gradually winning its place in the national economy as well.[3]

Dissatisfied with the USSR's progress in this revolution, an all-Union USSR State Committee on Computer Technology and Information Science was formed in 1986. The chairman of this new state committee, N. V. Gorshkov, said in an interview with *Pravda* on 17 August 1986, "The chief task of the committee is to unify the efforts of the ministries and departments in order to create and effectively utilize modern, highly efficient, and reliable computer technology, and also to oversee a unified scientific and technical policy in this field. A domestic information science industry must be organized and developed under the leadership of the committee."[4]

In 1988, *U.S. News and World Report* suggested the magnitude of the gap between the United States and the Soviet Union:

By one Soviet estimate, America's electronic marvels will make roughly *50 billion* more computer calculations per day than Soviet machines in 1990—a technological gap that is expected to widen dramatically by the turn of the century [emphasis in original].[5]

Clearly, the Soviets realize that improving conditions in their society and their image in the world means making peace with computer technology—a process still at the policy-making level in the USSR.

In all post-industrial countries, the information service industry is becoming a key component of the

economy. The worldwide demand for rapid, efficient transmission of data has emerged as a major industry, involving numerous devices ranging from satellites to fiber optic wire. The common element in this vast web of electronic activity is the semiconductor—casually referred to as the "chip." Arguably, the most important form of the chip is the microprocessor—a maze of transistors, diodes, capacitors, and resistors that makes up the circuitry essential to a computer's operation. It is this device which underpins most of the developments in the electronic digital computer.[6] However, the chip can also serve as a memory module, another key function in the information management process.

Surprisingly, as the performance of both the microprocessor and related computer memory increases, their respective costs continue to decline. Nonetheless, corporate revenues for leading Western producers continue to rise. This is primarily due to the industrialized world's seemingly insatiable appetite for information processing. In the United States alone, there were 38,425,000 computers of all types in operation by the end of 1987—and this number increases daily.[7] These figures contrast sharply with the USSR's computer industry and its planned production of "tens of thousands of computers per year,"[8] called for by Chairman Gorshkov of the USSR Committee on Computer Technology and Information Science. In production alone, the United States and USSR differ by three orders of magnitude, and such differences describe more than a matter of mere numbers. These statistical differences multiply even further when we examine the use of these machines. It is here that we find numerous indications of uncertainty and disagreement within the USSR over the proper and permissible use of computer technology.

At present the Soviet Union does not have a viable computer industry by Western standards. Even if the

Soviets were interested in marketing their computer hardware in the world marketplace, they would not be ready to compete. A 1984 report, written by Dr. Leo Bores, internationally known eye surgeon and medical software company president, after a visit to Moscow, says, "If ELORG [short for Elektronorgtekhnika, the Soviet trade organization responsible for the purchase, manufacture, and sale of electronic instruments and computers] plans to distribute the AGAT [the Soviet version of the US Apple computer] widely in the West they will have to cut the price dramatically from the $17,000.00 unit price [quoted to Bores]." That price is approximately 10 times the price of an Apple. An authoritative 1986 report on the AGAT places its value at $5,000, still many times the cost of comparable Western products. These reports also note that because of high costs and quality control problems, the USSR has abandoned the mass production of this machine.[9]

These estimates are in agreement with an assessment of Soviet computer production by Director Yury Nesterikhin of the Soviet Institute of Automation and Electrometrics in Novosibirsk. Nesterikhin also noted quality control problems and said that the domestic prices for Soviet microprocessors were 10 times the price of microprocessors produced elsewhere in the world.[10] Additionally, the numbers of units being built were insufficient to support international sales. While computer manufacturing and sales are numbered in the millions of units per year in the free world, comparable data behind the Iron Curtain are measured in the tens of thousands.

Evidence of the Soviet lag in domestic computer technology is not based solely on receipts for the sales of personal computers; support comes from reports of Sovietologists, experts in the field of information tech-

nology, and the statements and actions of the Soviets themselves. In 1985, estimates of the so-called "computer gap" between East and West ranged from 10 to 15 years.[11] Closing this gap in computer technology has been a goal of the Soviet leadership since the Brezhnev era. Until recently, the most noticeable effect of this objective has been increased efforts to acquire Western computer technology. With the advent of Mikhail Gorbachev the situation is changing. In his address to the 27th Party Congress, the General Secretary detailed his plan for renewing and restructuring the USSR's economy. Key to his plan is the role to be played by information technology in the next five-year period, 1986 to 1990:

- doubling the telephone system by the early 1990s,
- completing a national computer network,
- introducing computers and data bases at all levels of the national economy,
- training a new generation of Soviet citizens as computer literates, and
- reorganizing the USSR Academy of Sciences to correct the nation's computer backwardness.[12]

Obviously, Soviet leaders recognize the need to correct their country's deficiency in information technology. Because information handling permeates all facets of industry and trade, it is becoming central to the economic and political competition between East and West. Gorbachev acknowledges that what is at stake is the ability of the USSR to enter the next century in a manner worthy of a great power. However, announcement of this plan does not mean a mad rush to computerize the USSR, any more than it means a move towards Western-style democracy. As Henry Kissinger has noted, the aim of Gorbachev's reforms is not to appease the call for human rights from the democracies of the West. Rather, the Soviet elite seeks improvements in

efficiency, productivity, and technology as a means of increasing their power and influence around the world.[13] From the opposite side of the political spectrum, John Kenneth Galbraith feels, "The essence of the change [Gor[illegible]'s reforms], of course, is the effort to make more e[illegible]sponsive, open, and also honest the incredibly massive and stolid bureaucracy of the Soviet system, this on literary, artistic, political, and economic matters."[14] Regardless of the interpretation one encounters, Gorbachev's program is one of attempting to realign Soviet priorities and make better use of available technology. In short, change is in the wind in the USSR, and computer technology will be a central element in the process.

The United States and the rest of the free world must take pains to understand the Soviet predicament. For just as computer technology is changing the face of life and work in the West, it will have major effects in the Soviet Union. By examining available clues—indicators pointing to logical outcomes of the Soviet venture to create a more advanced computer culture in the USSR—we gain an understanding of Soviet prospects leading into what will be their own version of the Information Age.

Centuries of Causes

Initially, I will turn to history to put the Soviet dilemma in context. Aware of the use and abuses of Russian history by Western authors, I will not attempt to force disparate events into a preconceived "Grand Thesis" that explains Soviet troubles with computer technology. Nonetheless, the history of the Russian people is one of the clues that must be used to illuminate our vision of the Soviet prospects for realizing the aim of a more computer literate society.

Centuries of Russian culture explain an individual and institutional aversion to risk, an aversion which manifests itself today in resistance at the grass roots level to widespread use of computer technology. This chary feeling towards computers is reinforced by age-old Russian practices. As has been the case for centuries, Russian patterns of communication are based on personal contact within a close-knit cellular group. Consequently, the Russians do not regard the speed and impersonal nature of communication by computer as an asset.

Another Russian cultural factor that discourages computer usage is the strong tradition of authoritarian rule. The use of force augmented by control of information has been the hallmark of efforts to rule Russia for centuries. When the printing press was first introduced in Russia, the Tsar immediately declared it the property of the state. The ensuing state monopoly of print persisted for 250 years. Rather than being employed as a tool to eliminate illiteracy in the country, the printing press was used to disseminate copies of laws and decrees.[15] In much the same vein, shortly after the Russian Revolution of 1917, when Leon Trotsky proposed to Stalin that a modern telephone system be built in the new Soviet State, Stalin dismissed the suggestion, saying, "I can imagine no greater instrument of counter-revolution in our time." As a result of Stalin's words and subsequent decisions, the USSR now has the lowest per capita distribution of telephones – 10 per 100 citizens – among the industrialized nations.[16] Even today, the Soviet leadership does not see fit to make a telephone directory for the city of Moscow available to the public.[17] It would be, however, an oversimplification to view the present Soviet predicament as solely the "just desserts" of a decades-old national policy of information control,

pursued to the point of obsession. Many other factors are involved as well.

Among the forces that conspire against the exploitation of computer technology in the USSR is the longstanding systemic problem in Soviet scientific research and development—the tenuous link between R&D programs and actual production. When product obsolescence occurs at a nearly biannual rate, as is the case in the semiconductor industry, difficulties and delays in coordination amongst the agencies involved in Soviet manufacturing and quality control become a limitation that is magnified many times over. Commenting on problems with Soviet computer technology, Boris N. Naumov, Director of the USSR's Institute for Informatics Problems, said, "The biggest problem is that we do not have enough computers. It is not the design of the computer that is the main obstacle, but organizing production. It's the problem of developing a modern industry in computers which can provide what the users want."[18]

On a more philosophical level, the subject of cybernetics—a foundation of computer technology in the West—was originally outlawed and then accepted only conditionally in the USSR. The problem was one of incompatibile ideologies. Soviet communism accepts Marxism-Leninism as the universal doctrine and determinant of history—past and future. However, the self-correcting system (a key device also in the conceptual foundation of computer systems), based on feedback and control mechanisms, is believed to have universal applicability as well. To the Communist ideologue there cannot be two universal philosophies, especially when one may well lead to a different end. To speak of a symbiosis between man and machine was seen early on by the Soviet leadership as too threatening an idea to allow

even the elite scientists to read about.[19] While programs that continually refine the man-machine interface are the essence of Western computer software, for the Soviet, such studies are an ideological minefield. While it is one thing to acquire and reverse-engineer Western computer hardware (a task becoming increasingly difficult and a definite constraint on the Soviets' ability to keep pace with Western computer technology), the complexities and control issues inherent in managing large, user friendly expert systems with millions of lines of computer code amount to a major concern for the Soviet leadership. Akin to this point is the matter of the source of software. Ideologues brood over whether the user becomes "Westernized" by using computer software—compilers and application programs—that have been generated in the minds of Westerners. As party officials attempt to reconcile technology and doctrine, this is yet another contentious aspect in an arena often afflicted with paralysis.

These are the main issues. Some analysts have concluded that the scope of problems facing the Soviets in their race to catch up to Western information industry dooms their efforts, but we should not be too quick to dismiss their work. The Soviets desire different things from computer technology than we do in the West. We trust in market forces to sort out alternatives, and yield optimal results in computer hardware and applications. The Soviet GOSPLAN (State Plan) must articulate requirements before resources can be expended for such technology, and in the case of an "information machine" needs are carefully screened. Furthermore, the Soviets are masters at controlling the application of any technology in their society. Witness the case of the automobile, which many predicted would be the undoing of Soviet society in the 1950s. The car was adapted

to the system. A meager road network outside major cities and a system of controls (internal visas, police, roadblocks, and checkpoints) limit the mobility of the populace. Solutions to computer control are also possible. Already key Soviet officials speak in unison of the *kollektiv* use of computers in education programs that do not yet exist. Some experts have noted that while US organizations view their major computer security problem as unauthorized access from the computer opportunist ("hacker"), the Soviets will focus their security efforts on possibilities of operators and users "breaking out" of computer networks. For a Soviet, the prospect of a computer operator passing data out of his computer center without proper authorization is seen as an intolerable situation.

Because of the unique power of computer technology—both economically and culturally—the United States must carefully study how the Soviet system will adapt this force to its own ends. Some adaptation will occur—technological realities require it; the party has said it will be so. But a gradual evolution may prove to be inadequate for Soviet ends—too little, too late. Thus the West has reason to be concerned about dangers inherent in the Soviet situation. Should the rapid advances in microelectronics and applied computer technology alter the world's economy radically, as many predict they will,[20] the Soviets may see their national interests threatened by the expanding web of worldwide information handling activity. At the same time, to the extent that this technology changes society in the West, but not in the USSR, the world will likely become even more polarized—into two power spheres with less and less in common. A state of affairs which many would view as less than desirable. Another possibility meriting US concern is the effect that the absorption of computer

technology, to the degree proposed by Gorbachev and his supporters, may have on the Soviet Union. Internal changes could be of such scope and magnitude that they result in a Soviet State very different from the one we know today. Many would shudder at the sheer power of a nation as rich in natural resources as the USSR, should it be administered so as to function efficiently at its full potential.

It is an ironic state of affairs for the Soviets that their own ideology, which places science and progress on the altar for public worship, has been unable to absorb and exploit the computer – the basic tool of today's technological age. To understand the Soviet dilemma with regard to computers, consider how different computer technology is from traditional heavy industry. Because we refer to a computer as a "machine" and because our image of "machine" is something tangible, a mechanical product with moving parts, such as an automobile, airplane, power plant and so forth, we tend to so categorize the computer. But machines of the Industrial Era magnified man's physical muscle power. Admittedly the distinction is blurred when considering the use of the computer in process control, but even here the computer's role as a traditional tool is indirect. The task entrusted to it is to magnify man's cognitive abilities. In this context, computers perform no work themselves; they direct work. They are the technology of "command and control" as identified in the cybernetic theory of Norbert Wiener. In short, as a machine the computer has more in common with a clock than a locomotive – a device of calculation and measurement rather than a tool of raw physical power – an aid to the human mind.

In this sense, the computer is what David Bolter calls a "defining technology," that is, a technology that

collects and focuses disparate ideas or concepts in a culture into a bright and piercing ray.[21] Although Bolter stresses the philosophical and artistic aspects of his view, there is also a pragmatic facet to the view, which he eloquently traces in the course of human history. He explains that defining technologies define or redefine man's role in relation to nature. By promising (or threatening) to replace man, the computer is giving us a new definition of man as an "information processor," and of nature as "information to be processed."[22] We need only reflect on the changing nature of the work force in the industrialized world since the advent of the computer to see the wisdom in this message. The computer has not supplanted man but, rather, has been the catalyst for casting man in a new role. Nomadic hunter, farmer, craftsman, factory worker, information processor—so has unfolded the technologically driven aspect of man's development. It is the latter role—man as information processor—that is blossoming in Western industrialized nations. When coupled with the sister industry, telecommunications, human minds assisted by vast computational power can be put in direct contact with one another. There is little evidence of a comparable activity with computer systems in the Soviet Union. Rather, such issues must first be understood by party ideologues and state policies devised to deal with them before action can ensue.

The story of the Soviet dilemma with the computer is just unfolding. It is not a tidy package; it is a disparate collection of paradoxes and ironies. As with any complex issue, the task is not to assemble or organize facts; the real task is to understand the situation and its meaning and predict the outcome, interpreting the culture and motives of a world power with a political system antithetical to our own. The mixture of computer tech-

nology and Soviet tyranny was originally diagnosed as a natural and powerful combination.[23] This has not come to pass. Instead , the leadership of the USSR views computer technology as a dangerous force requiring much of their attention. At present, this Soviet struggle with computer technology abounds with uncertainty and significant potential consequence for the rest of the world.

2. Russian Traditions

THE PAST LARGELY DETERMINES the present status of individuals, institutions, and nations. How we prefer to think and solve problems derives, in large part, from personal experience and communal *tradition*. The force of past events and cultural mores colors our view of the present and, to a degree, limits our options for the future. Some may even argue that these factors, when properly understood, have predictive value. History also tells us that these practical aspects of the human condition—experience and tradition—are international phenomena. Thus, Russian historians and Sovietologists frequently offer us counsel regarding the interpretation of Soviet motives and actions based upon their insight into Russian and Soviet history. A notable example of this is the claim that the Soviets' exaggerated emphasis on military might is a logical reaction to a history of repeated invasion and conquest by adjoining nations. In a similar fashion, I believe that Russian and Soviet history tells us much about the present Soviet dilemma with computer technology.

William K. McHenry, a management specialist at Georgetown University, has compiled statistics indicating that less than 10 percent of the 44,000 industrial enterprises in the USSR possess computers. No other major industrial power in the world has such a low usage

rate of computer technology in the industrial sector. In explanation, McHenry points to "psychological barriers" hindering the use of computer technology in the Soviet Union. Interestingly enough, the term "psychological barriers" is not McHenry's own but, rather, appears frequently when the Soviets themselves discuss these issues.[1] As has become increasingly evident as the state's drive for computer literacy gathers steam, the Soviet bureaucracy and population at large appear inherently resistant to the use of computer technology. In print and in conversation, Soviet officials and academics bemoan the lack of computer literacy in their society but at the same time are less than enthusiastic about an alternative environment in which the computer is widely available and used. An uneasiness about how to control this technology is evident at the highest levels of the Soviet political hierarchy.

In the words of Dr. Yevgeniy Velikhov, Vice President of the Soviet Academy of Sciences, "One of the most important tasks before [the USSR] is to develop an interest in personal computers among consumers." However, Dr. Velikhov does not advocate saturating the land with personal computers as the solution. Rather, he reminds planners of what happened with Soviet-made electronic calculators: "The calculators have been gathering dust on store shelves for much the same reason as digital watches do; they are subject to breakdowns, no one knows how to fix them, and their batteries are rarely available." With vague reference to the "collective" use of computers as a partial solution to the Soviet predicament,[2] and with his analogy of the calculator and the personal computer, Dr. Velikhov reveals several of the factors that have combined to produce a Soviet society unsophisticated in the ways of modern computer technology. Poor product quality and

reliability, the absence of a technical base devoted to maintenance and repair, and an overall resistance to the use of computer technology—these are all very real problems for the Soviets.

Among individuals who visit or conduct business in the USSR, their accounts agree on the sharp contrast between the Soviet view and use of computer technology and that of the West. In even the better retail stores, open to escorted groups of tourists, retail clerks still use the abacus instead of electronic registers or point of sale terminals to tally a sale.[3] How could the two major camps of the industrially developed world so differ with respect to a technology that has become synonymous with progress? The answer is not simple, and is deeply connected with the history and traditions found in both the East and the West—it is here that we will find fundamental explanations for the current computer malaise in the USSR.

Survival and Suffering

Centuries of existence in a harsh climate and a history of struggle and suffering have combined to produce a Russian view of reality markedly different from that in the West.[4] During the formative period of the Russian experience, A.D. 1100 to 1900, the Russian peasantry lived on the narrowest of margins with respect to their economic and personal security. The communal and personal values derived from this history have endured for centuries and are enshrined today in Moscow's view of the world. Until as recently as 1900, peasants constituted 80 percent of the country's population.[5] Implicit in peasant life was a system, called an *artel,* in which the collective hierarchy of the village exerted control over the life of the individual. In exchange the collective assured the political and economic security of its

members. As we shall see, the leaders of the Communist Revolution in the Russia of 1917 were quick to recognize and exploit this village infrastructure and sociological conditioning to their own ends.

Russian peasants generally lived in the primeval forests north and east of present-day Moscow, an environment consisting of poor soil and a harsh climate. In this environment, the Russians chose to cope with nature by resorting to "slash and burn" farming as they roamed the forest.[6] Their constant battle with the elements and assorted invaders produced a bleak view of life as reflected in the poetry, short stories, and song of the common people. Subsistence agriculture in the harsh environment was a way of life that left little opportunity for the conduct of international or even interregional commercial activity. It also discouraged the incautious and adventurous among the population. Survival required constant attention, and the tried and true techniques prevailed as the method of choice.

The problem of merely surviving in this region was periodically compounded by hostile invaders. The combination of these two forces made it a virtual impossibility for the lone individual or single family unit to exist independently. The pattern of a collective unit, based on the village and a hierarchy of landlords, emerged over the centuries as the support structure most capable of assuring the survival and protection of the individual. In this system, all personal interests were subordinated to those of the group or the established authority figure. Behavior contrary to collective wisdom was viewed with suspicion and generally not tolerated. Unforgiving nature had demonstrated that there was simply no alternative to each household devoting 30 days per year to gathering firewood and 120 days each year to the gathering and storing of forage for the

livestock. The survival of each family's animals, as a source of food as well as fertilizer, was an important factor in the survival of the village as a whole, hence the emphasis on conformity. Numerous other tasks, equally exacting, were always carried out under the threat of a harsh climate. Violations of collective wisdom had too often proved fatal for the entire village. Thus, failure to comply with such established norms or innovative proposals which challenged the status quo simply were not – could not be – tolerated.

Edward L. Keenan summarizes the fundamental features of the Russian village culture relevant to this estimation well:

> [In the Russian village there was] a strong tendency to maintain stability and a kind of closed equilibrium; risk-avoidance; suppression of individual initiatives; informality of political power.[7]

During the early centuries of the Russian experience, the village provided discipline and social structure. It is also important to realize that during this time the Russian concept of collective effort had a heavy authoritarian flavor as opposed to a utopian cooperative bent. The story of Russian culture in the context discussed here is not akin to the idealistic spirit that motivated men and women to create a social utopia such as New Harmony, Indiana. In time, the subjugation of individual will was a norm transferred from the nuclear village to the national level. This was accounted for by the evolution of the role of the Russian tsar. Early tsars actually had little influence over the thoughts and conversations of the average Russians in their remote village setting. The farther removed from a major city such as Moscow or St. Petersburg, the less control the official body politic had over the actions of the peasants. The force that provided the glue for the Russian legacy of

an authoritarian rule of national scope rather than village scale was Russian Orthodox Christianity.

The church used its spiritual control over the people to exalt the notion of the *kollektiv* over the individual and reinforce the experiences of communal village life.[8] However, there was a pragmatic side to the role of the clergy as well. Without exception, clergy were literate, or at least quasi-literate. Thus it was probably natural that the ruling class enlisted the talents of the clergy as a tool to aid in the administration of the empire. Thus in time, the message of the church went well beyond spiritual matters and well-intended counseling. Clerics charged with administrative duties soon realized that by preaching submission to authority, their state tasks were less demanding. Through a close church-state alliance (in which land, influence, and power were bartered behind the scenes), the Russian Orthodox church used its sway over the peasantry to create and maintain the absolute (even divine) authority of the tsar.

British historian Lionel Kochan recounted some of the rather complicated story of religion and the tsars:

> The Church, because of its large landholdings, had played an active part in backing Muscovy's claim to Slav overlordship. From the fourteenth century onwards, the association of Church and State, which was much more intimate than anything comparable in Western Europe, had become closer, until by the early sixteenth century the Tsar had come to be considered a semi-sacrosanct personality with unlimited power, the earthly representative of God. To quote Joseph of Volokolamsk, the influential early-sixteenth century Abbot: "The Tsar is in nature like to all men, but in authority he is like to the highest God." It was thus, taking all these factors together, that the autocracy became, in theory, the divinely ordained fountainhead of an undifferentiated concentration of authority—political, in that the Tsar was the only political authority; economic, in that he claimed owner-

ship of the totality of the land; military, in that he led the country in war; religious, in that he ruled by divine right and was committed to maintain and defend the rights of Orthodoxy.[9]

Russian Christianity reinforced its authoritarian claims by extolling the virtue of self-sacrifice in the populace. More appeal was made to emotion than to logic. Visual stimuli were all-important to illiterate serfs. Thus the humility and suffering of the crucifixion of Christ were stressed to the point that the Easter week overshadows Christmas on the Orthodox liturgical calendar. Even monastic traditions stressed severity to such an extreme that many former monks' cells are now used as harsh isolation-punishment rooms in Soviet prisons.[10] In this way the church emphasized the virtue of suffering and self-denial—a national trait that has served many of Russia's leaders well.

Scholars who study this aspect of Russia's recent history note that this centuries-old trend still endures. Pointing out that Russia's major military victories have always occurred on the counteroffensive against an exhausted and extended enemy, Edward Luttwak focuses on the lack of and poor quality in Russian officer leadership as a principal factor in that legacy:

> The quality of junior officers' leadership and specifically their readiness to act on their own initiative count for much more on the offensive than on the defensive. It was in this regard that the Russians were at a great disadvantage. In a society rigidly hierarchical, in which a most strict conformity to rules and orders is imposed by draconian sanctions upon a people by no means as naturally disciplined as some, the habit is easily formed of passing all decisions to superior authority whenever it is at all decent to do so. Certainly the will to take action on one's own responsibility is more likely to be suppressed than in a more liberal society.[11]

Resistance to Change

Though the developed countries of the Western world have embraced computer technology in many forms, the transition to the widespread use of the computer has been neither painless nor universally welcomed. Resistance to change (often even beneficial change) is a universal human trait. The early days of the Industrial Revolution in the West abound with incidents of craftsmen and laborers engaged in often violent opposition to new and decidedly more productive processes. Yet entrepreneurs, and other men of vision, persisted in their application of technology, and in their inventiveness. The rest, as they say, is history. The same pattern is part of the story of the early application of computer technology.

Disagreement and duress often accompanied initial attempts to apply computer power to industry, as well as other fields, in the late 1960s and early 1970s. During that time, many respected figures in the field of management information systems and information technology, such as John Dearden, Robert V. Head, and Russell L. Ackoff, pointed out that few computerized management information systems had matched expectations and that many were outright failures.[12] Nonetheless, computer-based systems progressed in spite of resistance.

The principal driving force that has nourished widespread computer use in the West has been commerce. The advent of the personal computer in the 1980s has made affordable computer power readily available. Although it is virtually impossible to enumerate all the innovative uses of these machines, we know that in 1987 20 percent of white collar workers in the United States used computer systems regularly. In 1988 the figure rose

to 48 percent and an impressive total of nearly 90 percent of all white collar workers now use or have access to personal computers. The sales of such equipment are expected to rise similarly.[13] Today's free market, consumer credit, and checking account culture would not be possible without modern computers. By contrast, the Soviet Union does not have the sort of commercial organization which encourages computerization. For example, checking accounts and credit cards are unheard of.

The financial services that we in the West take for granted are just beginning to emerge behind the Iron Curtain. In June 1987, *Pravda* described the use of checking accounts in the German Democratic Republic (GDR). The tone of the Soviet news report was one of cautious support for the concept. This report closed with a brief mention of a concept it called the "money card." It described the money card being used on a trial basis in the GDR, a "noncash" payment system relying on the very latest in science and technology. No mention was made of such financial services techniques in the USSR.[14] Such differences are more than cosmetic and procedural; they also portend radically different approaches to the use of the computer.

Market Activity

The direction of progress for Western society was largely determined at the dawn of the Industrial Revolution. Of course such terms as the Industrial Revolution are by their nature generalizations, but in this case, it suffices to say that the Industrial Revolution describes a unique period in human history when the interdependent activities of manufacturing, commerce, and transportation underwent dramatic and relatively coincidental

change.[15] Like all benchmarks in history, these changes were perfectly obvious in retrospect but probably went unnoticed to many who lived the experience. To affix a date to the beginning of the Industrial Revolution would be as controversial as asserting the start of the post-industrial period, which many claim to be a matter of fact today. Nonetheless, it seems fair to say that by the mid-eighteenth century the Industrial Revolution was well underway and Great Britain had become the chief commercial nation of the world.

As with other periods of radical change and technological innovation, the advances that accompanied this period of manufacturing, transportation, and trading upheaval did not occur uniformly over time, nor were they readily accepted by all. For example, various guilds and tradesmen opposed and rejected the ways of industrialization and endeavored to expel its promoters from their midst. Similarly, it took an additional century for many of the developments associated with the Industrial Revolution to penetrate the self-imposed isolation of tsarist Russia.

However, despite the natural tendency to resist change, eighteenth century Europeans, and their American cousins, persisted both at home and abroad in their determination to harness the power of the machines and tools of the period. England embraced industrialization with a vengeance, soon emerging as the world's power broker and proprietor of a global empire. Under the protective umbrella of the Pax Britannia, the traditions of the marketplace and industrialization and an entrepreneurial spirit took root in resource-rich North America. By the middle of the twentieth century, in a hospitable and expanding business environment, the computer was quickly put to work, but this transition was not always welcomed, even in the West.

The demand for more and more business-related functions to be performed at faster speeds has continued to fuel advances in the domestic use of computer technology. In today's society, the omnipresence of the computer is a function of its natural role as a supporter of marketplace activity. Increasingly we see the importance of accurate and speedy information processing and communication in the world of commerce, and increasingly we turn to computer technology as a solution. This is not to say that this versatile machine has no other uses in our time. Certainly it is a valuable asset in national defense, science, education, government, and health care. But it is in the marketplace that the computer has performed well in its mission of magnifying man's power to process information. For businesses, large and small, it is no longer practical to return to green eyeshades and penciled ledgers as a means of managing financial affairs. We think nothing of dialing an advertised toll-free telephone number and then relaying our Visa or Master Card charge code to a voice synthesizer on the other side of the country to obtain the goods or services we desire. In this telemarketing process, computers are involved in switching our telephone call, recording, processing, and shipping our order, as well as billing and inventory control. As we shall see, the Soviet consumer is not psychologically disposed to conduct his affairs in such an impersonal manner, nor does the USSR's meager telecommunications system support such a process.

The Russian experience, as it dates back to A.D. 1100, is not one of market activity, industrialization, and world trade waiting eagerly to be spurred on by putting the computer to work. Indeed the Soviet economy is a paradox. Though its GNP ranks in the top five of the

world's nations – a measure of strength – the economy is widely regarded as flawed, even by Soviet leaders. Mikhail Gorbachev's publication, *Perestroika,* is in large part a collection of the General Secretary's thoughts and reflections on this paradox. Some Western Sovietologists, such as Marshall Goldman and Edward Luttwak, assert that a continued dominant role for the Soviet State is incompatible with its declining economy.[16]

An agrarian subsistence culture has been the true Russian norm. Contrary to events in the West, the prevailing patterns of human behavior and communication that evolved in Russia from 1100 to the early 1900s are not enhanced by the large-scale application of computer technology. Despite some modern trappings, Russian society has never really evolved beyond reliance on personal ties and relations for communication and the conduct of business. This limited communications picture is a natural result of the emphasis on localized village relationships and a historically poor system of roads and railroads at the national level. For example, today the Federal Republic of Germany, roughly one-tenth the land mass of the Soviet Union, has the same number of kilometers of paved highway as does the USSR and nearly one-fourth as many kilometers of railroads.[17] As Soviet expert Christopher Donnelly is fond of pointing out, outside the major Soviet cities, the country's road network is simply not comparable to that of the major Western European countries.[18]

The type and nature of human communication patterns that developed from this uniquely Russian environment are also relevant. The intimacy of the village structure, the formative setting for 80 percent of the nation's population into this century, fostered patterns of communication and interpersonal relationships based

on a small circle of close contacts. Even in the urban setting the pattern continues. Today 20 percent of the Soviet population lives in one-family, one-room apartments with communal kitchen and toilet facilities.[19] Taken as further evidence of the USSR's economic dilemma, this just may be an acceptable lifestyle for many Soviets.

According to Mr. John Joyce, a State Department official who served in the US Embassy in Moscow during 1973-76 and 1981-83, membership in these closely knit groups is evidenced by a complex system of nicknames known only to those in the group, a mechanism allowing one to avoid many of the risks found in society as a whole.[20] These patterns still prevail today. Within a scheme of groups and subgroups, key members of the group at one level are linked personally to a group at the next higher level. In this way, Soviet society's hierarchical structure is reinforced.

Modern historian William H. McNeill, in writing about the military-technological and political aspects of the pursuit of national power, provides an authoritative summation of this assessment. In explaining the mobilization of armed might, he attributes the rise of Western Europe as a world power to its reliance on market incentives to human action. McNeill makes a marked comparison of the European system with the "authoritarian command model" (based on what he calls "primary patterns" of human behavior) prevalent in Asia during the period A.D. 1000 to 1600. The "command model," anchored in the discipline of a rigid class structure and obedience norms, is sustained by primary patterns of human interactions that are ages old. However, in the modern era such systems were not able to sustain the types of economic specialization and

technological elaboration required to maintain large and well-equipped armies. This approach capitalized on the forte of the market system – flexibility and adaptability. McNeill notes that market activity brought on a radical change in human behavior at the time, saying, "Market relationships, on the contrary, tended to dissolve and weaken traditional, local, and primary [obedience] patterns of human interaction. Response to market incentives allowed strangers to cooperate across long distances, often without realizing it."[21] On this same point, Joyce states emphatically, "Market relationships have played no significant role in the history of the great mass of the Russian people.[22]

Luttwak also focuses on the effect of a culture void of market activity as a factor that explains the overall dismal history of Russian military endeavors from the Middle Ages and into the twentieth century.

> One talented commander-in-chief, or even several skilled and cunning generals, cannot suffice to direct the whole complex operation [battle]; it takes organizers and "managers" by the hundred to do that. And where in the old pre-industrial Russia would such men be found? Not among the bailiffs of lethargic estates, nor the old-style rural traders or small shopkeepers of the towns, and least of all could they be drawn from the state bureaucracy, where the deadening safety of procedure and the arrogance of petty power combined to strangle managerial talent.
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> When Tsarist Russia did belatedly industrialize . . . there was more need and more scope for management of good quality, and for all manner of organizational talent. But even then, an economy whose labour and many of whose basic resources were (and are) cheap, and whose products did not have to meet the test of the free market, would not demand high standards of efficiency.
>
> . . . It was the combination of the empire's geography and the defects of Russian society that crippled the potentially great military power of Moscow's rulers when they set out to wage war on a large scale against serious enemies.[23]

Thus, the historical picture of Russian life was noticeably void of the network of long-range and relatively impersonal associations that result from active participation in trade and market activity. Also absent in Soviet society as a whole is the tradition of risk-taking and innovation—the ultimate entrepreneurial traits in a market system. Thus history and sociology explain, in part, why the twentieth century dawned on an industrially backward Russia. We should note that this backwardness prevailed despite the intermittent efforts of various rulers, notably Peter the Great, to westernize Russia. This issue has often been the subject of much soul-searching and debate by the Russian intelligentsia itself. In 1829, Peter Tchaadayev, an aristocrat of St. Petersburg and Moscow, bleakly described his country:

> Confined in our schism, nothing of what was happening in Europe reached us. We stood apart from the world's great venture. . . . While the whole world was building anew, we created nothing: we remained crouched in our hovels of log and thatch. In a word, we had no part in the new destinies of mankind.[24]

And reflecting on the key role of the church in this situation, Tchaadayev concludes, "We were Christians, but the fruits of Christianity were not for us."[25] Tchaadayev was declared insane and placed under house arrest, but to serve the political ends of the times, eventually, his thoughts were printed in the Moscow journal *Telescope* in 1836. I would argue that Tchaadayev's observations are applicable to Russia's computer dilemma today.

The computer fulfills a key role in the material progress of the West; the capabilities of the computer facilitate the flow of information essential to free trade in Western society. We might expect, then, to the extent

differences prevail between the East and the West that the computer's usefulness and impact will vary as well. And so they do.

Soviet Adaptation

Even though Communist revolutionaries turned Russia into a major industrial power in this century, they have not changed fundamental Russian attitudes—many of which have proved to be valuable and convenient mechanisms for the present tyrannical system. For example, in today's Soviet society the concept of collectivism, which embraces every place of employment and ownership by the state, is the government's ultimate instrument of control. Members of the collective state (all citizenry) are required by Soviet law to cooperate with the Ministry of the Interior and KGB whenever and wherever requested. In effect, any state employee (and all Soviet citizens are by definition employed by the state) can be called upon at any time to divulge anything the government wants to know about another worker, friend, or relative. What the individual does not know he or she can be forced to find out. The withholding of information wanted by the state is an offense that can result in prosecution.[26] Such procedures, exercised either systematically or randomly, have the effect of constraining the free flow of information in the entire country and furthering the state's monopoly on information. With such a well-entrenched system, the use of computers as envisioned in George Orwell's *1984* is hardly necessary.

In sum, the driving forces behind the domestic uses of computer technology in the West—free market economy, individualism, competition—were not part of the formative Russian experience. In exploring the pat-

terns of human interaction and communication that grew out of the Russian struggle for survival, we find yet more evidence of attitudes and behavior that operate against an active role for the computer in contemporary Soviet life.

The form of subsistence agriculture that dominated the Russian scene from 1500-1900 had additional features that are relevant to the Soviet story. It was a stable system. While life was admittedly bleak and oppressive, the lessons of time and circumstance taught that traditional approaches to coping with the environment were able to provide for the individual as a member of a group. In turn, people came to expect that the hierarchy, as most immediately represented by the authority figure in the village, would exert a great deal of control over the group. In this way, society minimized the risk and responsibility of the individual for decisionmaking. Today this tradition is bolstered by the Communist ideology that provides a ready answer for every social, political, and economic circumstance. This latest system even frees the local leadership from risk.

Traditional communication patterns in Russian society are also part of the telling tradition that affects the absorption of computer power in the USSR today. The dominant pattern is based upon membership in a closely knit group, often using a system of nicknames known only to those in the group. This scheme enhances the controlled hierarchical structure favored by the party in the conduct of personal affairs. Exchanges laterally across the pyramid are sporadic, certainly not the official channel, and serve as a powerful means of compartmentalizing information. Thus, American scientists visiting the USSR are always amazed at how factories, institutes, and government offices work in isolation

from one another—each in its own universe, as it were. This lateral isolation, of course, works against good communications between institutions involved in research, development, production, and application of a sophisticated product or service such as computer technology. In the West, lateral communication and sharing of information takes many forms and has been judged essential to its thriving computer industry.

Neither the Russian tradition of face-to-face communication nor its hierarchical nature should be discounted—these characteristics have been and remain key characteristics of Russian culture. They underscore the limited potential for applying computer technology in Soviet domestic affairs. They also explain numerous reports of Soviet managers ignoring computer assets provided for their use or insisting on redundant face-to-face communication when a task had already been accomplished by an automated system.

Dr. Jeffrey Simon recounted an episode typical of the Soviet relationship with the computer once it is "up and running." In May 1986, while in Moscow attending a conference, Dr. Simon visited an Aeroflot office with a colleague. The purpose of their visit was to adjust a reservation for a portion of their flight before their departure from Moscow—a routine matter in any major airline office in any free world capital. Nonetheless, and despite the use of on-line, Japanese-made computer terminals that accurately displayed the reservation as it existed and as it was desired, nothing could be altered without the involvement of numerous office personnel at two different Aeroflot offices. At each location, lengthy face-to-face conversations were required to resolve the matter.[27] In general, Dr. Simon's brief encounter typifies the Soviet experience; even when ade-

Krokodil

What a clever machine. It actually calculates the losses incurred from its own lack of use.

Source. Reprinted by permission of *Soviet Analyst.*

quate and responsive computer equipment is available, traditional Russian communication patterns run counter to usage. The net effect is one of underutilization of scarce and sophisticated equipment, which in this case the government has expended hard currency to obtain. By contrast, users of computer-based information

systems in the West have been quick to capitalize on the extensive degree of lateral communications made possible with today's technology.

William K. McHenry, an analyst of Soviet management systems, reports that much of the computer hardware in the USSR has been classified "arrived but not yet working."[28] McHenry knows of instances where computer hardware was left in boxes outdoors for longer than a year and gnawed on by rodents. Although various sets of historical circumstances account for such "foot dragging" by bureaucrats and managers, the fact is that these same officials are not well disposed towards the equipment in the first place on purely pragmatic grounds. Even Soviet cartoons make humorous note of this point. Especially in industry, where the centrally planned economy puts Soviet managers under pressure to falsify production data to meet quotas, managers demonstrate an understandable nervousness about computer systems designed to monitor and report on plant processes. Not only does the Russian heritage of the managers run counter to embracing the computer, the practicalities of survival and advancement do too.

In the context of history, tradition, and culture, the periodic attempts by various tsars to make Russia more competitive with Europe and the similar efforts by this century's Communist revolutionaries are anomalies in the Russian experience. The revolution of 1917, arguably more a coup d'etat than a revolt, cleverly adapted itself to and built upon centuries of Russian history and tradition. The revolution, though dramatically successful in terms of the industrial capacity and military power it created, has been tempered by the influx of the peasant population that migrated or, more accurately, was forceably relocated to the major industrial centers of Stalin's

Russia.[29] This shift in the population infused old Russian mores—conservative risk-avoiding behavior, reliance on direct and personal communication, lack of market activity experience, and a willing deferment to authority figures—into the mechanics of the Communist state.

To this day, the influence of traditional Russian values, coupled with the bureaucratic inertia in the present Soviet system of national rule, not only explains a broad-based reluctance to embrace computer technology but also frustrates General Secretary Gorbachev's agenda for reforming the economy of the USSR. Recall that a major portion of this reform program deals with enhancing the nation's telecommunication system and generating a greater degree of computer literacy in the USSR. Predictably, the average Soviet citizen sees little benefit to either change. For today's Soviet citizen, his sense of history tells him there is little need for changes to the information flow in his life. His communication patterns are well established and he is comfortable with them. His sense of risk-aversion cautions that the more he knows, the more vulnerable and responsible he becomes—a consequence to be avoided if possible.

3. The Soviet System

THE SOVIET COMPUTER GAP is not a function of creative or mental inferiority on the part of individuals, ethnic groups, or races. To the conntrary, there is evidence that basic research in mathematical algorithms and compiler theory done by Russian mathematicians underpins many successful Western computer systems. Specifically, Soviet research was at the heart of a compiler (translation language) for the artificial intelligence language, Prolog, which the Japanese purchased for their most advanced computer research project, Fifth Generation.[1] Rather than intellectual ability, a commodity that no nation or race has a monopoly on, it is national leadership and national policy that are most directly responsible for the USSR's relatively poor position in the world computer industry.

The system—the way the USSR functions as a society and a government—contributes as much to Soviet computer woes as does the Soviet lack of sophisticated computer hardware and a national computer elan. From a systems point of view, the problem is one of application, not lack of capability.

The Ideology

Soviet problems with modern computer technology are compounded by the revolutionary methodology employed by the Marxist-inspired, Russian-Bolshevik

Communist Revolution. As with Russian leaders before them, the revolutionaries of 1917 were quick to use established Russian social norms to their advantage. As we have seen, conformity and subjugation, rooted in survival needs and reinforced by many social and religious mechanisms, have resulted in a traditional Russian disinclination to question authority and a tolerance of harsh government. These traits were aptly exploited by the Marxists.

In the process of promulgating the "truths" of communism, the new Russian leadership realized that a state monopoly on other types of information was useful as well. Thus the party soon filled the role of the principal provider of information to the people. As the strong central government of Moscow has perfected its means of producing and disseminating information, a pattern of communication and information control has been established that clashed head on with the development of computer technology. Here is how this has come to pass.

In his *Manifesto* of 1848, Karl Marx urges working men of all countries to unite and fight the political and economic pressures of capitalism, which if left unchecked will surely enslave the masses. In view of this Marxist doctrine, Russia was among the least likely sites for a Socialist revolution. Russia did not contain the requisite masses of proletariat oppressed by the capitalist bourgeoisie. Indeed, the vast majority of the populace (perhaps 80-85 percent) were peasants in rural areas oppressed by hundreds of years of quasi-feudal tsarist rule. (As late as 1950, two-thirds of the Soviet population was still rural.)[2] Market activity (capitalism) in Russia was essentially nonexistent before the revolution. Nonetheless, to make the Marxist-Leninist thought fit the situation, revolutionary leaders "created" a proletariat—

which existed primarily in the printed media. The Communist party began an ambitious program to educate the masses in the nature and scope of their oppressed plight under their prior state of capitalistic hegemony (this was a hidden agenda in the party's early national literacy campaigns).[3] That this deception was a fabrication by the party was of no concern. The party became the source not merely of ideology but also of "historical truth." This role of the party steadily expanded to include the control of all categories and sources of information in Soviet society.

Information control practices were a natural extension of tsarist rule and authoritarian village methods which were well-entrenched by centuries of practice. The party's practice of assuming responsibility for the dissemination of information in all situations it deems pertinent removes much of the burden from lower level officials charged with conducting routine affairs of government in small communities. These procedures were welcomed by low-level officials struggling for acceptance in the revolutionary environment. In fact, the elimination of risk to the lower level leaders, a familiar theme in village administration and Russian life, ensured the stability of their situation—a basically conservative outlook that accorded well with the values of the average Russian.

The techniques of information control have proven to be a highly effective means of controlling a country and enforcing rule. Soviet students of journalism progress in their profession only when they demonstrate ability to write material that arrives at the appropriate ideological conclusion, or the current approved viewpoint.[4] Having created such an information generating and controlling apparatus, however, Soviet leaders have

found it difficult to accommodate the entire spectrum of information-handling functions inherent in computer technology. The raison d'etre of the modern computer is to store, process, and retrieve information. Paradoxically, a society built on meticulous information control is troubled by the wide application of the computer to standard information processing tasks. For Soviet leaders, problems become even more troublesome when projecting the application of computer technology on a broad scale. Imagine 30 million or more personal computers in use in the USSR. It is one thing to control a mode of transportation such as the automobile; it is entirely something else to control an adjunct to the human mind.

Ideology as Science

Accustomed to rewriting history and censoring the information available to its society, the Soviet State has, in many instances, determined what has and has not been legitimate doctrine in academia and science. The appropriate organ for the Communist party to announce "correct" science was, and remains, the Academy of Sciences. From the earliest days of the Communist regime, it was recognized that the Academy of Sciences was the key institution in manipulating scholarship. Subsequently, a strong and direct subordinate relationship was established between the Academy of Sciences and the Council of Ministers—a relationship that persists to this day.[5] Further down the chain of command, the heads of subordinate research institutes exercise complete administrative control over their organizations and determine the direction of all substantive research.[6]

A prime example of the effectiveness of this party-academy arrangement is the tight control Trofim Lysenko held over the study of biology in the USSR. The impetus for the rise of Lysenko, the state-ordained ranking Soviet biologist for 25 years, was his personal drive to accredit the ideas of French biologist Jean Baptiste Lamarck, an early evolutionist who believed in the inheritance of acquired characteristics. In doing this, Lysenko hoped to reform Soviet agriculture. To attain his goals Lysenko

- attributed prior failures to obtain rapid improvements in important crop yields to the "bankruptcy of bourgeois science" (a phrase that will emerge again in the context of computer science),
- falsified his own data on altering the nature of plants by "suitable training,"
- and conspired to have Nikolai Ivanovich Vavilov, Russia's leading Mendelian geneticist and Lysenko's principal opponent, thrown in jail, where he ultimately died.

The results of the unholy marriage of biased science and authoritarian politics are eloquently summarized by Stephen Jay Gould in *Hen's Teeth and Horse's Toes.*

> Twelve years later, following the devastation of war, Lysenko had triumphed. His address, "The Situation in Biological Science," read at the 1948 session of the Lenin Academy of Agricultural Sciences, contains as the first statement of its summary what may well be the most chilling passage in all of twentieth century science.
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> "The question is asked in one of the notes handed to me, 'What is the attitude of the Central Committee of the Party to my report?' I answer: 'The Central Committee of the Party has examined my report and approved it.'" [Stormy applause. Ovation. All Rise.]

Following another ten pages of rhetoric and invective, Lysenko concludes: "Glory to the great friend and protagonist of science, our leader and teacher, Comrade Stalin!" [All Rise. Prolonged Applause.][7]

Lysenko had convinced Stalin to outlaw the teaching of Mendelian genetic theory in order to promulgate his own biological theories. For nearly two decades, Russian scientists were forced to adopt Lysenko's view that all living things, from wheat to man, could be sculptured by scientific training. Lysenko did not believe in genes. Until Khrushchev came to power in 1956 and released jailed scientists, the notion of genes and nucleic acids could not be discussed in the open.[8] Inspired by Lysenko's scientific ideology, Stalin expanded the practice of state-generated scientific dogma. During the 1940s and 1950s, Stalin forbade the study of cybernetics, electronics, and computers. The late entry of USSR science and industry into the field has been a handicap to the nation's computer industry even since.

Cybernetics, the philosophical foundation for computer science, was advanced as a scientific study by Norbert Wiener of the Massachusetts Institute of Technology in his 1950 book, *The Human Use of Human Beings: Cybernetics and Society*. Simply put, "cybernetics" is the term Wiener gave to the study of the common communication and control processes in machines, organisms, and societies. This concept has powerful academic appeal and is akin to general systems theory in its claim of univeral applicability. However, it was precisely the espoused univeral relevance of Wiener's philosophy that Stalin found objectionable. Only Marxist ideology was a truly universal creed, according to Communist party doctrine. Thus Stalin

directed that the study of commonality in the communication and control systems in machines and man be condemned as "bourgeois" science.[9]

Other decisions made by Moscow's postwar leaders further impeded the USSR's development and use of microelectronic technology. Stalin and his Politburo made two strategic decisions in 1945 – the USSR would restructure its industrial base to give heavy industry and the military the highest priority, and the USSR would do this on its own. The monolithic, centrally planned economy that had saved Russia from Nazi Germany would succeed without depending on the West for financial, material, or technological aid.[10] In fact, Stalin is quoted as responding to US Ambassador Harriman's offer of reconstruction loan assistance in 1944 by saying, "We appreciate what you are trying to do, but we have decided to go our own way."[11]

This same point is singled out for special attention by Mikhail Gorbachev in *Perestroika.* (His purpose is to explain the need for a new and less rigid system.)

> As young Soviet Russia started building a new society, it was all alone against the capitalist world, facing a need to quickly overcome economic and technological backwardness, and create an up-to-date industry practically from scratch. That was done with unprecedented clarity. . . . The management system that developed was meant to meet those objectives. It was severely centralized, every assignment regulated down to the last detail. It strictly posed and allotted budget sums. And it fulfilled its mission.[12]

For Stalin, the extremely centralized planning and control procedures, which he had instituted, were tested to the limit during the war and had proved to be superior. In this scheme, computer production was overseen by a relatively unimportant section of the Radio Ministry, both during Stalin's postwar years and

until 1965. In fact, the conservative Soviet military hierarchy insisted on retaining vacuum tube technology in its systems until well into the 1970s.[13]

The totality of Communist party control over the subject matter for its scientific research is hard for a people acccustomed to academic freedom to comprehend. Until the mid-1950s, it was forbidden to bring a reference book on cybernetics into the USSR.[14] During this period, to be caught smuggling documents on these subjects into the country meant being sent to a KGB detention cell at Lubiyanka. The intelligentsia, not always prone to intimidation, sometimes sought to pursue truth and modern ideas on their own. As a result, many prominent Soviet scientists found themselves in labor camps for their failure to submit to party policy regarding their work. Less dramatic, but equally revealing of the environment of Soviet science, has been the state's obsession with secrecy and isolation from information, not only from external scrutiny and sources of ideas, but from within its own hierarchy as well. This paranoia is particularly strong in scientific matters. To control the flow of information, the "first department" in every research institute is an arm of the Committee on State Security, better known in the West as the KGB. This office reviews all scientific papers and has complete authority to censor their contents.[15]

Naturally, such procedures retard the flow of scientific information. A Rand study of this matter noted that, in the late 1960s, the Soviets themselves found that the delay between the submission of a scientific article and its publication in the USSR was 12 to 15 months (as opposed to 6 to 8 months for journals in the West).[16] Another study conducted by the Soviets in 1965 confirmed the publication lag, and a third study in the late

1970s revealed an increase in the time required to publish material in the field of metallurgy.[17] In addition to problems associated with the censorship and screening of material submitted for publication, inadequate computer support for the processing of bibliographic data and cataloging was identified as a constraint in the Soviet system for dealing with professional publications.[18]

This issue of scientific publication has not changed with the advent of *glasnost*. In the summer of 1986, the USSR Academy of Sciences published a report on the nation's scientific and technical intelligentsia. The major aim of the study that led to this report was to identify ways in which the creative output of scientific collectives could be increased. Two major recommendations were made: to coordinate the actions of the various administrative authorities (bureaucrats) involved in Soviet science and to initiate a weekly scientific publication designed to share information and foster discussion on problems and issues of concern to the nation's five million working scientists and technical workers.[19] In this same study, half of those surveyed indicated they would like to change jobs by either leaving science altogether or transferring into teaching or another area of interest.

Clearly all is not well in Soviet science. Political and security considerations are still a large part of the picture for any scientist or technocrat. The view that individual scientists make decisions in response to political threats is still widely held. Young scholars are counseled not to study in a field that the government is interested in but, rather, to pursue a field that is extremely abstract.[20] In this way, new scientists can protect their individual security and, at least in a theoretical field, be creative. Even for scholars, neither life nor career is assured in the Soviet

Union unless one conforms to the restrictions posed in the party's ideology. This lesson has been learned so well that even when the party changes its position, the pace of change is slow and the resulting loss of time costly. In 1955, an article appeared in an official party journal, *Voprosy Filosofii,* criticizing the prohibition against the study of cybernetics. Nevertheless, the majority of Soviet scientists were cautious in their response, out of natural fear. As highly educated people, those scientists appreciated the irrationality of the situation from the start and learned to act accordingly. In the interim, much time was lost in training people in the knowledge of computers.

The atmosphere did not change until 1960, when Mstislav Keldysh, a Soviet authority in computer science and cosmonautics, was named Vice-President of the Academy of Sciences. His appointment and subsequent promotion (within a year he became President of the Academy) eased the psychological pressures on intellectuals and scientists who recognized the importance of information theory and computer technology and wished to study them. By this time US computers had progressed from vacuum tube technology to integrated circuits (ICs) in their hardware, and users were benefiting from the concepts of management information systems and data base management systems in the software arena. The industrial and commercial uses of computer technology were growing rapidly. Colleges and universities were establishing computer science programs tailored to many fields of study. Communist ideologues resolved the issue of cybernetics by defining it as technology applicable only on a level below that of Marxist ideology, and a philosophy in competition with Marxism. Once again the party had defined the world in

which its scientists could function, but in the process precious time was lost and the opportunity to gain experience forgone.

The Bureaucracy as Barrier

An international expert in all facets of computer-based information systems, James Martin has analyzed the friction between bureaucracy and computer technology in numerous situations. He summarized his findings best when he said, "Executives in bureaucratic organizations have a long and successful education in how to protect themselves and their departments. Computerized information systems threaten to wreck the carefully cultivated patterns."[21] This is as true of the Soviet dilemma today as it was of the Western resistance to computers in the 1960s and 1970s.

From the perspective of the Soviet system as a whole, much has been written about how efficiency suffers in a command economy with autocrats at the top and a domineering bureaucracy at their disposal. Key characteristics that have been used to describe the Soviet scheme for national functioning are

- exaggerated secretiveness.
- a price system that distorts scarcity relations.
- managerial incentives that reward plan-fulfillment irrespective of whether the plan makes sense and regardless of inefficiencies endured in the process.
- managers reluctant to innovate because of the risk such activity poses to plan fulfillment.
- "empire building" as a motivator in capital investment decisions.

- desire of enterprises to hoard labor, materials, and machines irrespective of their under-utilization.
- a tendency to oversize projects (bigger is better, or "gigantomania").

These characteristic inefficiencies manifest themselves in various ways. Compared to the United States, the USSR applies 2.75 times as much labor and invests twice as much capital to produce each unit of GNP. The USSR uses 2.2 times as much land to achieve a unit of agricultural product.[22] Of course, Soviet leaders will refute the generalizations in the list above and counter the data quoted with facts of their own. Nonetheless, it remains a curiosity that the objective analytical capability of large computer-based systems is avoided and the centrally planned system endures. Even the criticism of General Secretary Gorbachev has not been sufficient to effect a noticeable turnaround in the functioning of the overall system. So again we see friction. And the friction is evident in the way science and research are conducted, the way government programs are administered, and the way enterprises are run. Let us begin with science and research.

The Soviet system has shortcomings in scientific research and the application of that research in society. A disconnection between the fruits of "pure" scholarly research and its practical application has become a hallmark of the Soviet system, and this is not solely a Western view. In 1983, the Chief of Staff of the Soviet Armed Forces, Marshal Nikolai Ogarkov, published a pamphlet that criticized Soviet military technology and pointed out that, increasingly, the United States is the producer of breakthrough technologies.[23] Ever since then, Yevgeniy Velikhov, Vice-President of the Soviet

Academy of Sciences, and his supporters have criticized interagency barriers in the Soviet bureaucracy that hold back the USSR's computer industry as well as other areas of technological progress linked to computer technology. Velikhov views this situation as a key factor inhibiting the development of Soviet computer technology.[24] Compartmentalization of people and information is a key problem for the Soviets in this situation.

Despite the rhetoric of change, the sheer number of governmental organizations at the Ministry level that have influence over the development, production, and distribution of computer technology hampers the Soviet plans for advancement. These organizations include the Ministries of Communications Equipment Industry, Electrotechnical Industry, Radio Industry, and Electronic Industry. Because of the importance currently being given to narrowing the computer gap in the Soviet Union, no Ministry will willingly forfeit its influence in the interest of efficiency. Consequently, the Soviets have succumbed to fighting this bureaucratic fire with more bureaucracy. The new Academy of Sciences Department of Informatics, Computer Technology, and Automation, which is being directed personally by Velikhov, consists of 12 institutes, at least 4 of which are new creations designed to duplicate and circumvent the functions of the rival Ministries.[25] Rand researcher Simon Kassel suggests that the reorganization (shown in figure 1) is a response to the US Strategic Defense Initiative. The timing of Velikhov's reorganization supports this view. In Velikhov's mind, the creation of a Soviet information science industry is a priority requirement directly linked to Soviet security. Thus, an information science industry must be created, or Soviet

security will be jeopardized. As Soviet Military General Staff spokesman Yuri Lebedev remarked in 1987,

> At the present stage of the military-technological revolution, the progress in information technology . . . begins to play a decisive role and increases by many times the combat effectiveness of all weapons. There is a direct interconnection between space militarization and the "information" of the arms race. Some Western specialists consider that the very possibility of introducing SDI appeared only when information technology reached a high enough level of development.[26]

If this interpretation is correct, then the efforts in Soviet computer technology in their defense sector are not as advanced as we have believed them to be.

The contradictions in the Soviet system do not stop here. It is also ironic that, while the Communist ideology extols the notion of scientific and technical progress, adequate computer support is sorely lacking in both scientific and educational circles in the Soviet Union. Mikhail Gorbachev himself has addressed the problem, calling for a national computer network, the introduction of computers and data bases at all levels of the national economy, and training of a new generation of Soviet citizens as computer literates by 1990.[27] However, thus far this is only rhetoric, and old-fashioned rhetoric at that. In 1964, one of the original works of GOSPLAN (USSR State Planning Committee—a government agency in charge of long-term and current planning of the country's economic and social development and control over the fulfillment of those plans) was declassified. In this national planning document, the Soviet leadership called for the development of a nationwide command and control computer network. At that time it was estimated that 40,000 computers would be required to achieve this goal. Reports

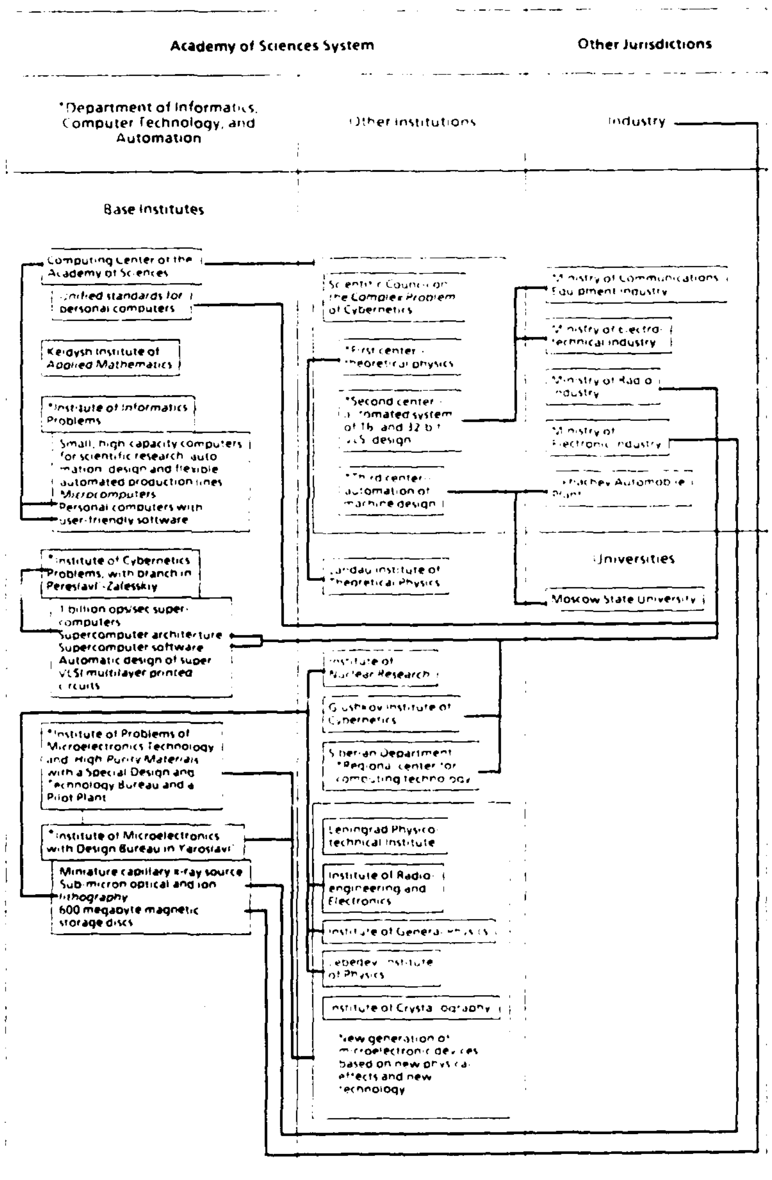


Figure 1

Reorganization of the Academy of Sciences in the computing technology area.

from Western experts such as Carl Hammer, Goodman, and McHenry, who have studied this issue in detail, reveal that the Soviets are no closer to operating this system now than they were in 1964.

This frustrating situation is best summed up by Komsomol Central Committee Secretary Aleksandr V. Zhuganov in a 1986 article on the contribution of Soviet youth to accelerated scientific and technical progress. After discussing the need for more progress in this area to spur socioeconomic development in the USSR and appraising the success and failure of various programs directed at the problem, he concludes by saying

> We cannot fail to be concerned also by the circumstances that in recent years the attractiveness and prestige of scientific work has declined among young people. The efficiency of postgraduate studies remains low. . . . No more than 15 to 20 percent of graduate students defend their dissertation within the stipulated time. In a number of cases, after the young scientists have earned a degree or a title, they stop growing as creative workers. Nevertheless, they continue to earn regularly high wages for past accomplishments rather than present results.
>
> The full manifestation of the creative potential of the young scientific and technical intelligentsia is frequently held back for other reasons. Sociological studies conducted among young scientists and specialists within the USSR Academy of Sciences indicate that about two-thirds of them are dissatisfied with working conditions, availability of instruments and equipment, the work of scientific and technical

Note. The figure 1 activities with asterisks are new and are intended to address the problem of computer illiteracy in the USSR.

Source. Reprinted from "A New Force in the Soviet Computer Industry: The Reorganization of the USSR Academy of Sciences in the Computer Field" (N-2486-ARPA), August 1986, the Rand Corporation, 1700 Main Street, PO Box 2138, Santa Monica, CA 90406-2138. Reprinted by permission.

information services, wages, and possibilities of professional and career promotions. Sometimes the creative thrust of young inventors is dampened by the obstructions encountered by an author who tries to put his creation to practical use. A great deal of valuable time is wasted as a result of red tape in processing technical documentation! A great deal of effort is lost on endless initiating of totally unnecessary coordination agreements. All of this must be firmly rejected.[28]

What Zhuganov says about Soviet science in general goes right to the heart of the impasse in computer technology. High-ranking Soviet administrators have begun to realize that their own cumbersome bureaucracy has effectively strangled progress in the vital area of computer-based information systems. Although such statements should not be interpreted as calls to dismantle the Soviet system of centralized state control, they do indicate a realization that too much bureaucratic interference does stifle scientific progress.

The Struggle to Change

Clearly, a major theme of Soviet restructuring under Gorbachev is a drive to develop a computer-literate society. Apparently, the Soviet leadership has come to realize that increasing the numbers of computers in the work place is of little value without a work force capable of using them. Thus the Soviets have instituted some computer literacy programs, occasionally with bizarre results. Mr. John Aldriedge, exhibit manager for the 1987 US Information Agency, who spent nearly three years in the Soviet Union since 1966 in conjunction with various cultural exchange programs, reports that a Russian friend's 17-year-old son was studying the computer language Basic in one of the Soviet model schools, without the use of a computer; all instruction and problem

solving was accomplished with chalk, pad, and pen. Mr. Aldriedge noted that in other schools where computers were available, the printers were closely controlled and, in the absence of direct supervision, kept under lock and key.[29]

One might argue that such an environment is not drastically different from that in which Fortran, Basic, or Cobol was taught in US institutions during the 1960s and 1970s. Indeed, many readers recall their own experiences with coding sheets, key punch rooms, and customer service windows. However, the point is that current Soviet methods of computer education are a far cry from the interactive teaching and learning environment made possible in the West by an abundance of personal computers and extensive use of computer networks. These telling details, as reported by Mr. Aldriedge and others, indicate that the Soviet approach to computer education and literacy is at least 10 to 20 years behind that of the West. Given the rapid acceleration in computer skills training and usage in the West, it is difficult to foresee how any approach short of rapid and radical change can close the widening gap.

The Soviet scientific community has always emphasized theoretical work over practical application. Note pad, pencil, and chalkboard are the principal tools of scientists because routine experimental equipment—especially computers—is not normally available. But perhaps the Soviets themselves do not desire it to be any other way. Dr. Carl Hammer, an international computer science expert, points out that although the Soviets have trained some of the world's most notable mathematicians, statisticians, and probability theorists, they have a discernible bias against computer science. The accomplished Soviet researcher shuns the computer

field while talented and promising students are discouraged from studying computer science.[30] Other US experts concur in this view. Taubes and Garelik report that the best and the brightest in the Soviet system actively seek theoretical work as a means of avoiding direction from incompetent party bureaucrats.[31]

These patterns are clearly established by the views of those who manage the Soviet educational system. Dr. Gennadiy Yagodin supervises all of the USSR's higher education, with an enrollment of five million students at the university and research institute level. In 1986, for the first time, he had permitted students to use calculators when taking examinations. In an interview with Michael Woods, Soviet science and medicine researcher, Yagodin expressed his concern that computer technology would seriously jeopardize Soviet science, saying, "This could be a great problem. There is a Russian poet who wrote that computer technology can lead to the degradation of the human brain. I am very troubled by that possibility."[32] Again this is an insight into the thoughts of a conservative national leadership and intelligentsia troubled by the approaching shadow of computer technology.

Without question the Soviets have their share of brilliant scientists in many fields. The system, however, has often shifted their professional efforts. Professional and elite scientific groups have been intimidated and coerced to the point that they cower before the party. The techniques of control are perhaps less overt than those directed at the masses, but the results—conformity and obedience—are the same.[33]

In a lecture at the Smithsonian Institution on 15 October 1986, Dr. John Thomas, US State Department, analyzed Gorbachev's new policies as they relate to

Soviet science and technology. He noted that Soviet science is expected to

- contribute to the national economy,
- enhance the state's military capabilities, and
- further the prestige of the USSR.

Today there are many indications that the Soviet leadership is not pleased with the ability of its scientists to accomplish the first task, and some would deny their effectiveness in the last area as well. Since the first electronic computer was built in the United States in 1947, all related discoveries and developments—transistor technology, semiconductor technology, large-scale circuitry integration, and most recently breakthroughs in superconductor materials—have been the fruits of the Western system of progress promoted by a free enterprise system. Soviet leaders must find it disconcerting, and probably embarrassing. Consequently, they have instituted reforms in the scientific community as in other parts of the society. Top scientists working in the military arena have been shifted to industrial duties. The goal is to bridge the traditional Soviet gap between the theoretical work that takes place on the blackboard and the actual production of useful goods in a factory.

But simultaneously, other measures have been introduced that constrain the Soviet scientist.[34] Newly added and more stringent rules limit interaction between Soviet scientists and their counterparts in the West. Restrictions on visits to private homes, always officially limited, are being enforced with increased diligence. Shorter papers are the order of the day, and distribution has been reduced—typically from 3,000 copies to 300. The old pattern of bureaucratic compartmentalization is still the norm in the USSR. Foreign scientific journals circulate very slowly in the USSR; 18 months from

receipt to dissemination is the typical delay imposed by censors. To our knowledge, they have no automated library retrieval systems, meaning that some information is hopelessly lost in filing and cataloging.[35] These restrictive practices further highlight the gap between Gorbachev's rhetoric and actual results.

Internally, the publication and exchange of working papers and reports among Soviet scientists [illegible] limited or nonexistent. The system also lim[illegible] among its own scientists. A researcher in Leningrad is likely to be largely ignorant of the progress of his fellow scientist. in Novosibirsk. Arthur A. Hartman, US Ambassador to the Soviet Union from 1981 to 1987, recalls that he had occasion to introduce two prominent Soviet scientists, of world class reputations in their fields, during a dinner party at his residence. Prior to that evening the two men had never met nor spoken to each other.[36]

As you might suspect, such isolationist practices are far from the norm in Western science and technology. There the free exchange of ideas is the lifeblood of scientific progress. We can identify numerous manifestations of Western practices in science and technology that are the antithesis of those seen in the USSR. The "job-hopping" reputation that computer professionals, especially in the United States, have acquired is one of the sharpest contrasts. At first viewed with alarm, the high mobility of computer professionals has actually promoted progress by a kind of cross-fertilization of ideas between companies. This mobility of ideas, combined with venture capital, has served to propel computer technology to ever higher achievements. The constant dialogue between engineers and programmers keeps companies from resting on their laurels and forces continued innovation. To be sure, there are unwritten rules

in this game of information interchange, and corporate loyalty is still a valued concept, but high job turnover rates and professional competition have been the key to many a successful system and product.[37]

Both domestically and internationally, the practice and dissemination of Soviet scientific thought is restricted. Again, compartmentalization is sometimes treated as an end in itself. The limited volume of scientific material published in the USSR is an indicator of these restrictions. According to *The New State of the World Atlas,* science is molded by the work of a very few countries. In 80 journals accounting for over 25 percent of all citations in science journals, the principal countries in this work are the United States, United Kingdom, Netherlands, Denmark, Sweden, Switzerland, Israel, and Thailand. The USSR ends up in the lowest category of participation, along with Venezuela, Ghana, Algeria, Egypt, Turkey, Pakistan, and India.[38]

Focusing specifically on computer science research, the July 1984 report of the Foreign Applied Science Center sums up the Soviet situation. The eight distinguished international computer scientists who compiled this report analyzed 900 translated papers and scanned thousands of others. Their report says

> Much of the published work [in the USSR] is pedestrian, even by the standards of ten years ago. The caliber of current research can rarely be judged as good or exceptional. The published papers often contain known results, or minor variations of known results. Conspicuous by their absence are even a few outstanding pieces of work that address completely new issues or point to new directions of research. Few ideas not familiar from the US literature are encountered; where seemingly novel work in programming systems or languages appears, it seems contrived. The pragmatic ineffectiveness of Soviet theoretical computer science research also contrasts oddly with a Soviet tendency to surround discussions of

engineering subjects with mathematical formalisms far more abstruse and elaborate than those by US authors writing on comparable subjects.

Our generally negative assessment of the work reported in Soviet computer science research should not be allowed to obscure the fact that expanding activity is manifest in many areas that Soviet researchers previously found inaccessible because of the general inadequacy of the hardware resources available to them. Overall, the Soviets are seen as trying to catch up with the United States; but, despite expanded activities, the gap does not seem to be closing.[39]

Applications

The situation for the Soviets is an extremely ironic one. At the behest of Lenin, science was to be the foundation of "unparalleled progress of production forces."[40] Yet it seems the system cannot accommodate the most basic tool of present-day science and technology, the computer. From a Western point of view, the bond between Soviet tyranny and technology has not developed as expected. Less than 20 years ago Western observers published major concerns that the computer would be used to violate individual rights and invade personal privacy. Though the alarm was meant to apply to all forms of central government, the obvious focus was a totalitarian state, such as the USSR. Orwell's *1984* and Huxley's *Brave New World* foretold a horrible, centrally directed state rule, made possible in part by computer technology that provided the "party" with a means to record and recall the details of a person's life. Though such tyrannical information control has not yet come to pass, it is not for the lack of technology, which is more capable than ever of accomplishing the data processing tasks for a *1984* scenario. Indeed there are signs such a data management

capability is in the hands of Soviet leaders. Dr. Ernest F. Philipp, international lecturer on the subject of computer architecture, has personally been the object of a major Soviet computer personnel monitoring system. While visiting in Poland in 1986, he discovered that every detail of his travels and financial transactions conducted in many cities and towns had been systematically recorded, stored, and retrieved for verification against his passport and official papers prior to his departure from Poland.[41] Such efficiency of information management is indicative of what Soviet leaders will be capable of when fully equipped with a master computer data bank. But they seem hesitant to move in that direction.

For whatever reason, Soviet leaders seem to prefer to retain the man-in-the-loop, rather than institute a national data bank of Orwellian proportions. Such a data bank, one that could record a great body of information on every Soviet citizen of consequence, is possible should the government modernize its computers.

Lower level bureaucrats and plant managers have other reasons for shunning automated record-keeping systems. Experience tells them they have good reason to be wary of the computer. Professor Rett Ludwikowski, now with the Catholic University Law School, Washington, DC, and formerly a law professor in Poland, had witnessed senior police authorities in southern Poland "proofreading" (report altering and padding in Western terms) periodic reports on criminal activity in their regions of responsibility. The purpose of such a review was to ensure that the report submitted was in accordance with the results desired. Professor Ludwikowski told of a typical incident in which crime report figures were revised downward.[42] Such proofreading, a common practice and virtual self-destruction for computer-based information systems, is receiving more attention at higher levels. Increasingly referred to

by the more appropriate title of "report padding," it is criticized frequently by General Secretary Gorbachev.[43] Even Soviet ideologues realize that the computer technology truism of "garbage in/garbage out" is equally applicable on both sides of the Iron Curtain. However, should tightly controlled central planning, such as GOSPLAN, come to rely on a nationwide network of computers for its source of planning data, the effects of "proofreading" could well be catastrophic.

The application of the computer in industry differs little from that in government administration. One of the most telling reports on the application of Soviet computer power in management appeared in the November 1986 issue of *Communications of the ACM.* In their report, William K. McHenry and Seymour E. Goodman summarize the use of management information systems technology in the USSR. They remind us, as does Dr. Carl Hammer, that the Soviet concept of a nationally networked computer-based information system is at least 20 years old.[44] Relying heavily on information from Soviet sources and their own travels to the USSR, Goodman and McHenry found that the absorption of automated management systems in Soviet enterprises is small. The official Soviet title for such systems is the Automated Enterprise Management System (ASUP).

In Soviet industry the ASUP attempts to foster five objectives:

- Maximize production,
- Keep inventory levels at an efficient minimum,
- Identify and release excess labor,
- Account for industrial capacity, and
- Evaluate performance via appropriate audits, correlations, and analytical tools.

The stated goals of ASUP provide clues as to why Soviet plant managers and their staffs view them with distrust. As contemporary Soviet analysts, such as Hedrick Smith and David K. Shipler, tell us, the limited goals of these mid-level managers differ markedly from the grand scheme for the entire Soviet economy as envisioned by the central planners. From their more practical perspective, plant managers are concerned with

- Fulfilling this year's plan with an eye towards the anticipated objective for the next year.
- Hoarding supplies and labor as protection against an order to surge production, or at the very least to meet quota at year's end.
- "Proofreading" (doctoring) reports so that plant capacity can be cleverly understated and performance overstated if necessary.
- Avoiding the divulgence of detailed accurate information to superiors.

Computer capability permits the ASUP to record, store, retrieve, and analyze heretofore unmanageable masses of production data, thereby allowing central planners more direct control of day-to-day industrial and plant operation. The weight of empirical evidence strongly suggests that Soviet plant managers have so far successfully resisted automated data management and are not likely to change their attitudes.

Learning to cope with Soviet central planning, the Soviet mid-level managers are better off not using the automated support provided to them. The Soviet economy works on the basis of a production quota. Straightforward production, or report of its achievement, is rewarded, rather than innovation and shrewd decisionmaking. The under-the-counter deals and secret cache of funds and resources used to succeed dare not be

the subject of official reports.[45] Soviet managers are assisted through this caldron by the bureaucrats. They find sympathy in the bureaucracy for resisting computer-based management information systems. How else can we explain the scarcity of operational ASUPs in Soviet industries despite some 20 years of effort? Only 7.5 percent of the centrally controlled state enterprises have implemented ASUPs. Again here is a paradox and clue that something is amiss. After all we are dealing with an authoritarian system that should be able to readily dictate the terms of top-down implementation for a concept such as ASUP.

McHenry and Goodman note that if the USSR is to realize Gorbachev's goal of a 150 percent increase in productivity by the year 2000, it must make much more effective use of the computer assets available to management within industry. But years of Soviet neglect to this area have squandered the opportunity to train and develop a cadre of personnel to operate, use, and refine computer-based management information systems. Lack of personnel experienced in the ways of the computer is a major contributor to the Soviet problem in applying computer technology. Although the use of computer technology in the workplace could provide a means of on-the-job-training to overcome this weakness, no trend to train such personnel on any appreciable scale can be found in the USSR industry today.

We have seen how the inherent system of one party rule and the modus operandi of state-controlled science contribute to a Soviet technological backwardness in computer technology. This fact has been recognized and reported by Western scientists and professionals visiting and working in the Soviet Union. The gap in the

development and application of computer technology is also the target of a long-range recovery program advocated by the leadership of the USSR, but the results have been disappointing. Little in the system has changed fundamentally; the leadership is in a quandary. Soviet leaders now realize that a national program to advance computer literacy and usage is needed, but they are also aware that to achieve that end requires basic changes to the Communist system. To conservative party members steeped in the Marxist-Leninist doctrine, such changes are not an acceptable option.

Konstantin Simis, author of *USSR: The Corrupt Society*, supports this view emphatically, pointing out that the Soviet system has evolved into a "partocracy" in which the party and government have been fused as one. The overriding goal and value are that of preserving the political structure through which the leadership has risen. Simis warns that Western leaders should not be fooled by "cosmetic changes and tactical deviations" in Soviet policy, "for domestically and internationally, what the new [Gorbachev] generation has in mind is more of the same."[46] This seems a logical explanation of what we see happening in the USSR. In any event, the Soviet system and how it is manipulated by the national leadership constitute a powerful force in retarding the application of computer technology within the USSR.

4. Hardware

THE PHYSICAL DEVICES that collectively make up a computer system are referred to as computer hardware. A common element in every computer hardware device is some version of the semiconductor, a marvel also known by its colloquial clone, "chip." Technological advances in this computer hardware have been startling since the introduction of the electronic computer in 1947, making the ability or failure to keep pace in computer hardware developments a major factor in determining winners and losers—players rather than spectators—in the dawning Age of Information. Computer chips have become the equivalent of a cherished natural resource, as important as our sources of energy. In today's world, chips are essential not only in computers but in the tools of all major industries, in scientific instrumentation, and in military weaponry. As has occurred before with other national industrial resources, such as ship building and steel and automobile manufacturing, the capability to produce computer chips can be taken so much for granted that its existence is threatened. The present friction between the United States and Japan regarding computer chip manufacturing is evidence of this state of affairs and is only mentioned here to underscore the importance of semiconductor technology to the leading industrial nations.

In a field that was the exclusive domain of US firms as recently as 1984, Japanese manufacturers are now a leading force.[1] Japan's new-found strength in this area is reported with increasing frequency and, in some quarters, with alarm. Corporate and government leaders at the national level speak of this matter as a major geopolitical issue. The US Congress has passed legislation authorizing the President to restrict or prohibit proposed takeovers of US semiconductor manufacturers by Japanese firms, based on considerations related to national security as determined by the Secretary of Commerce.[2] Clearly, technology for manufacturing computer chips is viewed at the highest levels of government as a vital national resource and one with far-reaching ramifications, in both economic and military terms. This connection between chip technology and national interest has not escaped Soviet leaders and is undoubtedly a factor in their decision to upgrade their own computer industry.

The gap in computer technology between East and West is often described in terms of the East's shortages and inadequacies in computer hardware. For example, to date the USSR has developed only 15 distinct microprocessors, 6 of which are direct copies, even to part numbers, of US-manufactured devices. The Soviets consider machines such as the IBM PC and the Apple II so valuable that they are "reserved for the state military, and party elite."[3] Nonetheless, to envision the Soviet computer gap as solely a hardware issue is an oversimplification. We should be aware from the outset that as central as hardware is to this discussion, it is but one component in an organization's or nation's overall ability to exercise computational power. Though admittedly short of sophisticated computer hardware, the USSR

has proven itself capable of exercising the computational resources needed to conduct military, space, and other tasks of the highest priority. Not only are the Soviets lacking in state-of-the-art hardware, they do not have the capability to maintain those machines they do possess. Computer-based systems are only effective when supported by adequate levels of customer engineering service and maintenance. Poor, inefficient maintenance appears to be an inherent weakness to the Soviet industrial system in general and is not peculiar to the computer industry.

This analysis will touch on all these points but with an orientation to the present state of computer hardware.

The Semiconductor Setting

Computational power can be viewed as a three-dimensional diagram. This scheme suggested by John Hershey of BDM Corporation has the following components.[4]

(1) Hardware. In the dimension of hardware, the physical machine itself, the semiconductor dominates today's computer technology. Its two principal forms are the microprocessor or "chip" and the main memory storage, which uses a slightly different form of chip design. In addition to these primary elements of computer hardware, there are several major forms of auxiliary storage, as well as peripheral and special-purpose devices such as controllers and multiplexers, also categorized as hardware. The real or tangible device is currently the essence of hardware.

(2) Architecture. The system configuration or the way various types of computer hardware are linked into

an operational system is the architectural dimension of computational power.

(3) Algorithms. The remaining dimension is that of algorithms—the mathematical models used to solve problems appropriate to the computer. Particularly in complex systems, mathematical models provide the skeletal structure upon which programmers mold the code that we ultimately refer to as software. The subject of software will be addressed in more detail in the next chapter.

Comparable degrees of computational power can be achieved by emphasizing various combinations of the three elements—hardware, architecture, and algorithms (software). As illustrated in figure 2, the Soviet ability to generate the requisite computational power for conducting space and military programs is a function of emphasizing advances in the dimension of mathematical algorithms to compensate for computer hardware deficiencies. For example, it is widely recognized that Soviet scientists established the principles of linear programming—a widely used technique in complex manufacturing processes in oil refineries and chemical plants worldwide.[5] Also, they may have accomplished many purely scientific and research projects relying on analog computers. However, analog computers are so ill-suited to administrative and commercial data processing applications that they have been almost entirely supplanted in the West by the more versatile digital computer.

In the context of this model, I would argue that the West and the USSR occupy different relative positions, which explains how comparable degrees of computational power can be achieved in different ways.

The developed countries in the West, and Japan, have emphasized the production of successively more

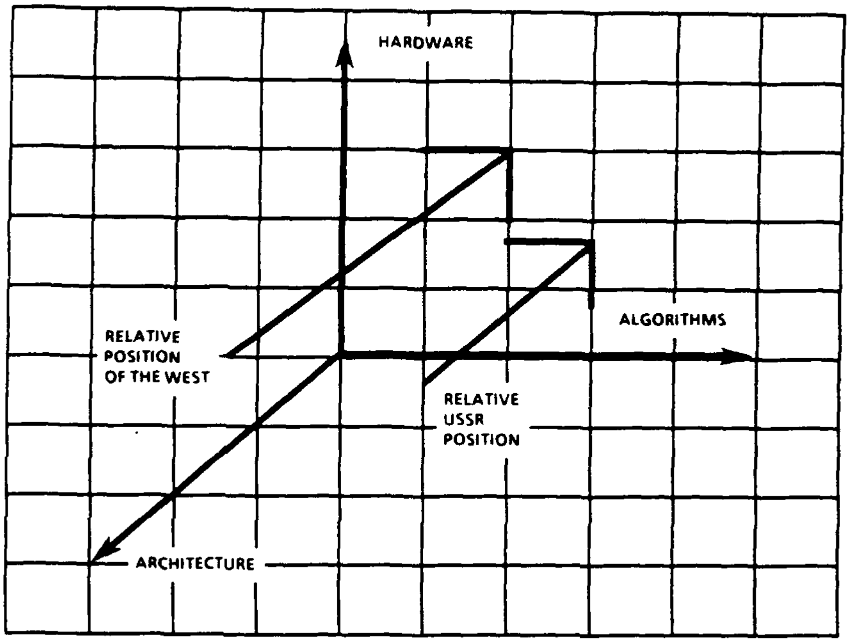


Figure 2

Relative computational power of the US and USSR.

Source. Adapted from a model by J.E. Hershey, "The Cutting Edge of Defense Computing," *Defense Science and Electronics* 5, no. 11 (November 1986): 22.

capable computer hardware to steadily enhance their prowess in the computer industry—progress based largely on the technology of the semiconductor. The principles of semiconductor technology are so well known that producing simple semiconductors is attainable by any organization or country which desires to pursue it. Thus, the manufacturing of chips for use in early generation personal computers is a capability within the

grasp of any industrialized country. The key determinant for computer capacity is operating speed—measured today in millions of operations per second of time (mips) which a chip can accomplish. Speed, in turn, is directly related to the number of logic gates—comprised of transistors, microscopic vacuum tubes with an infinite operating life—that can be assembled from semiconductor material and organized in extremely close proximity to each other.[6] The advancement of this technology in the West has been truly dramatic since 1965 but particularly so in the early 1980s. As figures 3 and 4 show, this improvement in computer operating speed (mips) and the density of logic circuitry respectively has been uniformly increasing for the types of computers widely available in the West.[7] As more and more logic gates and associated circuitry are confined to a smaller and smaller space, the production process becomes very sophisticated, requiring specialized equipment and engineering. Memory, the ability to store information for the central processor to act upon, is another key determinant of hardware capability. Figure 4 depicts recent progress in this area.[8] Why and how these developments in hardware technology have come about is a key part of the story of current Soviet computer "backwardness."

Contrary to our expectations from other industries, increasing hardware capability has come at a steadily decreasing cost—a situation which makes the steady growth of this industry all the more impressive. As figure 5 shows, the cost of the computer computational capability shown in figures 3 and 4 is decreasing as rapidly as capability is increasing. This is also true in the category of computer memory, as reflected in figure 6.

For the West the situation, as depicted in the preceding figures, is proving to be a most pleasant

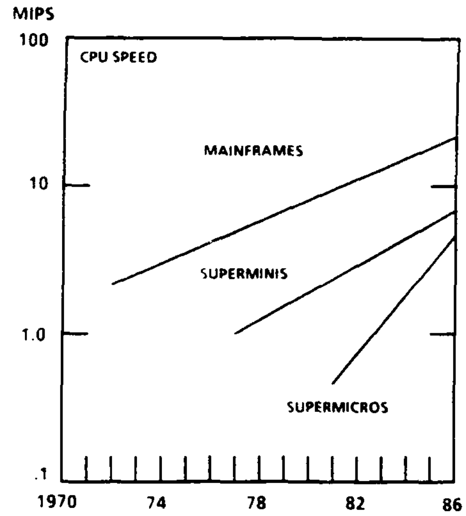


Figure 3

Number of millions of ordinary instructions per second that can be executed by a single central processing chip.

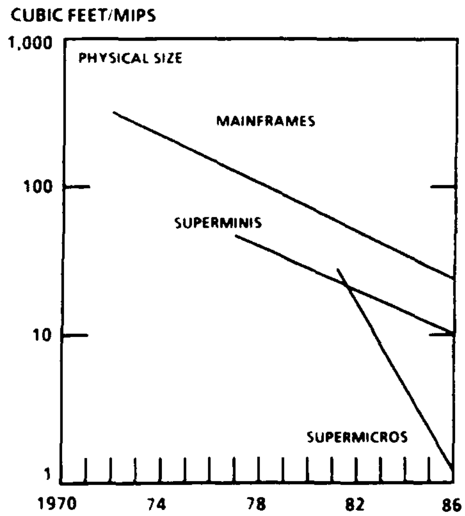


Figure 4

Physical size of the central processing unit per millions of instructions per second.

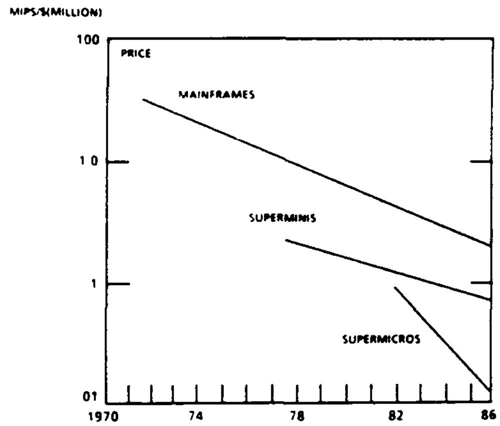


Figure 5

Cost per million of instructions per second performed.

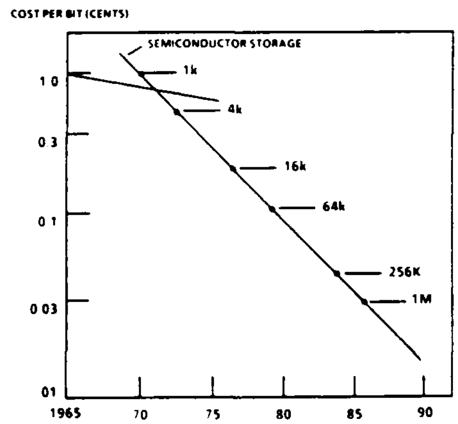


Figure 6

Density of storage of bits of data per semiconductor.

Source. Donald H. Sanders, Computers Today (New York: McGraw-Hill, 1985), p. 113. Copyright 1985. Reprinted by permission.

market trend from the viewpoint of consumer and supplier. More affordable computers bring their power to more and more users, thus permitting suppliers to remain solvent even though the price of their product declines each year. The entire situation is a technical manager's dream—a favorable and predictable trend line. As an IBM executive recently put it, "Our large customers are increasing their demand for computer power by 50 percent every two years. No other industry has that kind of growth curve."[9]

These advances in computer technology rely upon computer-aided design (CAD) and computer-aided manufacturing (CAM) technology. Originally semiconductor chips containing 1,000, 4,000, and eventually 64,000 electronic devices of microscopic size were designed by electrical engineers using manual—pencil and note pad—procedures. It is possible for the human mind to create and comprehend an entire 64K chip without the direct aid of a computer, even though a hard copy of the documentation for such an electronic circuit covers the floor of a basketball court.[10] However, as more and more electronic circuitry is packed onto a single chip, the use of computers and specially designed computer software—or collectively CAD—is required to complete and test the design of a new chip. Figure 7 is a simplified representation of the CAD/CAM process.

Today, the story of Western computer technology is basically circular: ever more capable CAD/CAM technology yields a more capable finished product, some of which is used in turn to produce more capable CAD/CAM technology. The latest product yielded from this technological cycle is a semiconductor capable of storing a staggering four billion pieces of data (a 4-megabyte chip).[11]

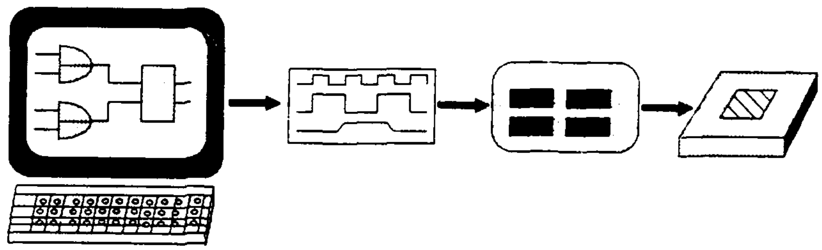


Figure 7

CAD/CAM process: design, simulation/testing, manufacturing, final product.

This CAD/CAM capability of the West is closely guarded by the major commercial hardware producers and is the object of trade embargoes advanced by the US Department of Defense in the interest of national security. CAD/CAM is also expensive technology, even in the absence of trade barriers. Today's CAD/CAM, x-ray lithographic etching equipment, and laser-based defect removal systems, all of which are essential to producing chips capable of storing in excess of 1 billion bits of data, will soon cost $1.0 billion per factory.[12] The possession of CAD/CAM technology is only a first step. Experienced and well-trained operators of CAD/CAM technology are probably more important to the ultimate end of producing ever more compact and capable chips.

The problem is essentially one of scale and complexity. As more and more circuits are etched into a smaller and smaller space, the task of copying or reverse engineering a microprocessor becomes increasingly difficult for the person without knowledge of the designers' original intent. Although the basic circuitry of an "AND" or "OR" gate can be readily identified, its relationship to the millions of other such circuits in the chip

is known only to the original design team. In the case of Western producers, motivated by proprietary interests, the design may be deliberately masked and complicated to protect a company's market and discourage competitors from duplicating their work. Of course the individual intent on copying a chip can use sophisticated computer technology to analyze and decipher his target chip. But again, in the case of chips with millions (now approaching billions) of circuits, the task is both time consuming and complex. One must determine which terminals are used for input, which for output; some may be dummies; others are dedicated to redundancy and error control—the combinations are almost endless. Arguably, such effort would be better spent creating one's own original design, rather than attempting the copy.

Historians and scientists have long been aware that the capacity to use technical knowledge is as important as the possession of the knowledge itself. This is the definition of the concept of "know-how." In the main, "know-how" is transmitted personally and consists of a noncodified skill acquired by direct exposure to and participation in a work process. A favorite example of this concept is the craft of making wooden barrels. Though there exist many sets of coopers' tools in the United States, no one "knows how" to use them.[13] Given the complexity of the CAD/CAM process the same argument is applicable to an even greater degree. As if balancing these factors were not challenge enough, the entire process is taking place in an environment of accelerating change. The chip changes; this changes software capabilities; this results in new capabilities for the designer, who in turn designs a new chip. Thus far the cycle has been more of a spiral: each design iteration yields improved capabilities at an accelerating rate. The

acquired experience, knowledge, and skill of chip manufacturers also have become a jealously guarded resource of Western manufacturers. Manufacturing techniques are as valuable as device design; skills, timing, the identification and control of critical variables in the manufacturing process are all essential to producing a quality product efficiently. In sum, successful companies must be active and innovative in this technology if they desire to remain in business. Play to win and win to play are the essence of this rapid technological spiral.

The critical value of advanced CAD/CAM technology is one of the main points in the 31 December 1986 Task Force Report on Semiconductor Dependency issued by the Defense Science Board. The report addresses the tension between the United States and Japan in the semiconductor industry and outlines an ominous scenario for the future: heavy US dependency on foreign sources for state-of-the-art semiconductors. Emphasizing the interrelatedness of chip technology, the Defense Service Board issued this series of conclusive statements.

- Technological superiority is key to superpower status—both militarily and economically
- Semiconductors are key to microelectronics, the heart of today's advanced technologies.
- Owing to the high cost of human and material capital involved in the manufacture of advanced semiconductors, high volume production and large commercial markets are essential to offset development costs.
- Failure to engage actively in semiconductor manufacture results in a loss of leadership in the field and reliance on foreign sources for state-of-the-art semiconductor technology.

We can readily see how this situation fits the Soviet case. Because of embargoes and high capital investment costs, Soviet manufacturers do not have the ability to produce state-of-the-art semiconductors in the quantities they desire.[14] Of course, smaller chips, such as the 64K chips (the mainstay of early personal computers such as the Commodore and TRS-80), are capable of impressive computing accomplishments and can be organized into even more capable components using imaginative architecture. Nonetheless, such arrangements cannot possibly outperform a single more capable computer chip. This limitation becomes clear when developing mainframe and supercomputers for huge administrative tasks and national command and control networks. Smaller, less capable chips are simply not up to the task.

Exactly where USSR equipment can be plotted on the preceding charts cannot be known with certainty. Some US experts familiar with Soviet computer manufacturing technology maintain that the Soviets are unable to mass produce a computer as sophisticated as the Apple II.[15] We know that the Soviet Union and its satellites are producing chips in the 64K to 256K range. With semiconductor capacity increasing by approximately a factor of four every two and a half years (a technological generation), the Soviets are at least two generations behind the West in this aspect of computer technology.[16] Even this may be a conservative estimate of the situation, by the Soviets' own admission.

The dean of the Department of Computer Mathematics and Cybernetics at Moscow State University, in a short piece in Moscow *Kommunist* on 2 January 1986 calling for more and better computer training for Soviet students, in the process, made several revealing comments about the USSR's computer technology. He noted

that Soviet computers had begun to change qualitatively (and subsequently described Soviet computer hardware as "inadequate" in supply and "unreliable") and that updating occurred e 7 to 10 years.[17] In this case, the Soviet computer gap vis-a-vis the West was compounding itself by a factor of three every 10 years.

A 1985 report announced that USSR computer producer Elektronorgtekhnika in Kiev had begun producing an equivalent of the VAX-11 computer. This was Digital Equipment Corporation's follow-on technology to the PDP-11 of the 1970s. The VAX technology was also one of the first capable of using vector processing algorithms to enhance its performance. This same report went on to note that the Soviet VAXs were not as powerful as their original Western template. Furthermore, by 1985 Digital Equipment had gone far beyond the VAX-11/780 technology.[18]

As for numbers of computers, the current Five-Year Plan for 1986-1990 calls for the USSR to achieve a total installation of 1.1 million microcomputers by 1990 and for the production of all computers to increase by 140 percent during the period.[19] Part of this production is the new SM-1700 small computer system. The Moscow Domestic News Service reported in September 1987 that the manufacture of these new computers had just begun in Vilnius in southern Lithuania. The report concluded by noting that "several scores of this new computer will be made by the end of the year."[20] At this rate it will be difficult to meet the goal of over a million new computers by 1990. By comparison IBM did produce over one million Personal System/2 computers in 1987.

Though far behind the West in computer capability, Soviet scientists have built many hardware prototypes. Indeed, some experts assert that the Soviets

design so many prototypes that this hampers their ability to achieve volume production.[21] Obviously such proliferation of nonstandard hardware only magnifies the problem of training operators, programmers, and maintenance personnel. In terms of the speed in commercial data processing computers, US computer scientists report Soviet indigenous capability of 150-200 thousand operations per second for their commercial data processing computers.[22] At the supercomputer end of the spectrum, the Soviet BESM-6, a collection of imported computer parts, is thought to perform 10 million operations per second (mips). Western supercomputers, of which 160 mostly US-built machines exist (the other primary producer being Japan), are capable of between 700 and 1,000 mips. In practical terms, this means that problems requiring 48 hours to compute on the BESM-6 will be finished in approximately six minutes on the Cray-1A, US supercomputer.[23] This disparity will become even greater as the latest US supercomputer, the Cray X-MP/4 or Cray 2, becomes operational. In 1987, this machine operated routinely at six times the speed of its Cray 1 predecessor. Machines in development now by Cray Research will perform at 10 times that speed, or 56 billion operations per second, by 1990.[24]

Again, the Soviets' own words shed light on the current state of their computer technology. On 17 April 1987, *Pravda* printed the address of General Secretary Gorbachev to the Communist youth league, Komsomol. The general thrust of his speech was to urge the youth of the USSR to support his reform measures. By way of example, Gorbachev boasted of the recent achievements of Soviet young professionals in the field of computer technology. Specifically, he cited the development of a

multipurpose computer capable of executing 125 million calculations per second and claimed that this machine was being "phased into full-scale production." Gorbachev went on to predict that within the next five years the USSR would create a computer capable of performing 10 billion calculations per second.[25] Setting aside for a moment the doubts we have about the credibility of such statements and the sustainability and reliability of any equipment the Soviets would be likely to produce, it is immediately obvious that what the General Secretary had chosen to laud and cite as an example for select Soviet youth is old hat by Western standards.

The Soviets themselves, though frequently claiming to be developing computers capable of speeds in the range of 200-400 million operations per second, make a point of repeatedly asserting that reports of the computer revolution passing their country by are an exaggeration. But they do not deny that the USSR lags behind the West in the production and use of computers.[26] In this respect, we must be careful of the context and the semantic differences between the languages and cultures involved. As Dr. Carl Hammer points out, "mass production" for IBM means the production of one million personal computers per year or one every 31.5 seconds. When the Soviets speak of "mass production" in their computer industry, they mean a yield of closer to 5,000 units per year.[27] With such small-scale production, the sale of home computers to Soviet citizens has allegedly just begun. The DK-0010, with 16K of random access memory, has been sold sporadically in one branch of the Moscow chain, "Elektronika."[28]

Dr. Richard Judy of the Hudson Institute has thoroughly researched Soviet domestic computer hardware. The summaries of his lengthy studies are shown in

tables 1 and 2. They reveal a conclusive Soviet backwardness compared to the most commonly available Western hardware.[29]

Table 1

Basic performance characteristics of Riad-1 and Riad-2 computers

Model	*Country of Manufacture*	*Operations per Second (Thousands)*	*Main Memory (Kbytes)*	*Input/output Multiplex Rate (Kb/s)*	*Channels Selector Number*	*Rate (Kb/s)*
Riad-1 Computers (original specifications)						
ES-1010	Hungary	10	8	160	1	240
ES-1021	Czech.	20	16-64	35-220	2	250
ES-1020	USSR, Bul.	10-20	64-256	25	2	300
ES-1030	USSR, Pol.	60-100	128-512	40	3	800
ES-1040	GDR	320-400	128-1024	50-200	6	1200
ES-1050	USSR	500	128-1024	100-150	6	1300
ES-1060*	USSR	1300-1500	256-2048	100-150	6	1300
Modified Riad-1 Computers						
ES-1012	Hungary	6	128	20		
ES-1022	USSR, Bul.	80-90	128-512	80	2	500
ES-1032	Poland	180	128-1024	145	3	1100
ES-1033	USSR	150-200	256-512	70	3	800
ES-1052	USSR	700	1024	425	2	1250
Riad-2 Computers						
ES-1015	Hungary	12-16	128-256	20	1	160
ES-1025	Czech.	40-60	128-256	24	1	800
ES-1035	USSR	120-140	512	30	4	800
ES-1045	USSR	500-850	1024-409	40	5	1300
ES-1065	GDR	450-600	512-4096	40	4	1500
ES-1060	USSR	1300	256-2048	110	6	3000

* *Note*: The ES-1060 was shifted into the Riad-2 era.
Source: Richard Judy, Hudson Institute Report HI-3872, 1986.

Table 2

Modified Riad-2 and early Riad-3 computers

Model	Country	Operations per Second (Millions)	Maximum Main Memory (Mbytes)
ES-1011	Hungary	.1?	1
ES-1016	Bulgaria	.1?	1?
ES-1026	Czech.	.1	1
ES-1027	Czech.	.4	4 *
ES-1034	Poland	.3	4 *
ES-1036	USSR	.4	4 *
ES-1046	USSR	1.3	4 *
ES-1056	GDR	.5	4 *
ES-1061	USSR	2.0	8
ES-1065	USSR	4.5	16
ES-1066	USSR	5.5	4 *

* *Note*: May have been upgraded to 16MB after 1985 when larger RAM chips were scheduled to become available.
Source: Richard Judy, Hudson Institute Report HI-3872, 1986.

As we shall see, the Soviets started late in the conceptual stage of computer hardware design and elected to pattern their machines after successful Western computer hardware technology, rather than strive for an original design of their own.

A Late Start

The theoretical framework for the production of modern computer hardware is found in the science of cybernetics and microelectronics production techniques. During the 1940s and 1950s scientific pursuits in electronics, computers, and cybernetics were officially

banned by Stalin—a position dutifully endorsed by the Soviet Academy of Sciences.[30] These subjects, the foundation of today's high technology electronic world, were labeled "bourgeois pseudosciences" and their study was forbidden. Stalin's policy delayed the development of a scientific and academic foundation for the study of the computer in the USSR. With the passage of time, this limitation in the study of computer technology has resulted in relatively small numbers of educators and scientists trained in computer science, a low level of computer literacy in Soviet society, and a reputation for computer hardware that is cumbersome, out-of-date, and unreliable.

While computers were in the prototype stage, nuclear power became a reality. By 1948, the USSR had a functioning nuclear reactor; by August 1949, they had exploded a nuclear bomb; and by 1953, they had produced a hydrogen bomb capable of being delivered by an airplane.[31] With this formidable series of events as a background, the 1957 launch of the first Russian satellite resulted in shock and near hysteria in the United States. Numerous scenarios for the initiation of disaster from outerspace on a defenseless US dominated news reports. Massive catch-up programs in science and education were quickly instituted so the United States might recover from the situation. The Marxist dictum that a society based on scientific and technological revolution had an awesome power and the ability to raise civilization to new heights seemed to be shaping reality. A genuine fear and despair gripped much of the West, but there was a silver lining inside this dark cloud. Or, viewed another way, the proverb—necessity is the mother of invention—was to receive yet another endorsement.

Soviet space technology at the time developed rocket boosters capable of placing large payloads into earth orbit. (This was largely a product of Stalin's systematic expropriation of German scientists after the war.) Thus, Soviet satellites were much larger but not as well crafted as their US counterparts. (This drive to always build the bigger version of an object as a means of demonstrating prowess has been dubbed "gigantomania" by the Soviet press.[32]) The first US satellite, *Explorer I*, weighed 31 pounds, while *Sputnik II* weighed 1,120 pounds, carried a live dog, and was recovered from earth orbit intact. The smaller US satellite, however, contained sophisticated electronics that enabled scientists to discover the earth's Van Allen radiation belt.[33] This contrast in scale and substance was a foreshadowing of the USSR's present plight in computer technology. Without the ability to place large payloads into orbit, the US space science and engineering effort was forced to miniaturize payloads. Transistors and integrated circuits, the forerunners of today's microprocessor or "chip," were the result. In turn, successful miniaturization soon gave way to today's microminiaturization.

In exploration of outer space, the reliance on raw physical power instead of sophisticated microelectronics is still the hallmark of the Soviet program. The USSR has launched more than twice as many payloads into space as the United States, but US satellites remain operational three times longer than their Soviet counterparts. Longer service life results from more reliable and capable microelectronics in US space vehicles. Higher quality negates the necessity for more launches.[34] The key element in our space program is sophisticated microelectronic technology—a product of Western invention and

development, and a mainstay of contemporary Western technological prowess.

It was not until 1965, with the creation of the Ministry of Electronics, that the production of computers was shifted from a relatively unimportant section in the Radio Ministry. By this time IBM was introducing the first commercially available third generation computer, the System 360. Because Soviet-made chips could not operate at low temperatures, the Soviet military did not view computers as rugged enough for their uses. Consequently, the priority afforded or given to the computer industry in the USSR was still low.[35]

The Choices

In the late 1960s, driven by market demand, the computer industry in the West blossomed. Mass production and technological advances made the computer available to all organizations. At the same time, Soviet advances in this field were inhibited by a lack of commercial demand, a cumbersome bureaucracy, and a centrally planned economic system. Nuclear and space research were the Soviet postwar priorities, and the computers that existed to support these highly classified programs were uniquely designed prototypes built for a limited purpose.[36] Although knowledgeable Soviet intellectuals were well aware of the issues at stake, they disagreed on how to proceed.[37] The Slavophiles, Russian isolationists led by academician Sergei Lebedev, argued that regardless of the progress being made by the Western computer firms, the USSR must maintain its own research and development programs in this field. The pro-Western faction lobbied for a program to obtain and copy Western designs and equipment as the most practical way to keep pace. This approach was

meant to circumvent Soviet backwardness in computer design at that time by allowing someone else to assume inherent R&D costs. The latter argument prevailed. The target decided upon was IBM, and the decision committed the Soviet Union to a modus operandi it still follows—that of copying the computer industry of the West (and Japan).

As a result, during the period of detente in the 1970s, the Soviets made deliberate efforts to acquire entire computer production factories from the United States. As relations between the two superpowers cooled, the United States cancelled these programs; nonetheless, the Soviets acquired much of the technology they desired by other means.[38] Consequently, today's Edinaya Systyema (Unified System) mainframes, made by the Radio Industry Ministry's facilities in Kiev, Minsk, and Penza, are patterned after the IBM 360- and 370-series computers. Minicomputers are the domain of the Appliance Industry Ministry's Systyema Malikh (Small System) and follow the architecture of Digital Equipment Corporation (DEC) and Hewlett-Packard equipment. The Soviet Elektronika microcomputers contain the same architecture found in the DEC PDP-11.

By 1972 the Soviets had realized the full magnitude of their error and made their first major attempt to close the computer gap. The sleepy Russian village of Kryukovo, within an hour's transit from Moscow, was transformed into the Soviet version of Silicon Valley. Fifty thousand people were assigned to work in the three construction plants, eight institutes, and college which make up the renamed Zelenograd Study Institute. Although the goal was self-sufficiency for the USSR in electronics, the methods were still inefficient by Western

standards. In the area of advanced high-quality hardware only limited quantities for military use were forthcoming. Key projects fell behind schedule and the computer technology gap continued to widen.[39]

In the 1980s, the Soviets have attempted to replicate DEC's Micro-VAX system.[40] However, owing to the difficulty of reverse engineering such a complex machine, the Soviets are also simply trying to acquire DEC machines—specifically the VAX 8600 product line, a high-end mainframe computer.[41] While imitation may well be the sincerest form of flattery, for reasons of national security neither DEC nor other US firms are permitted to sell the USSR such computers.

Copying the design of existing computer hardware has never been a panacea for competitors in either the West or the USSR. Dr. Carl Hammer likes to remind colleagues that when IBM announced its 360 series of computers, RCA immediately set about to copy the machine. Although RCA did manage to build and market its IBM-clone Spectra series, it failed as a competitor in the industry. Similarly, early Soviet efforts to copy the IBM System 360 were also failures.[42] In 1976, a Riad-40 (IBM 360 clone) was purchased from East Germany by an independent research agency in Washington, DC. Upon close inspection the Soviet Riad computer proved to be far less of a machine than its IBM counterpart of the previous decade. Although advertised as able to do calculations as fast as its namesake, the IBM 360, the Riad-40 could not sustain that speed for more than a few minutes, after which time a sensor would activate and reduce the operating speed by a factor of two.[43]

While on the subject of copying computer hardware and in fairness to the concept of maintaining a

competitive posture based on following the industry leader, we should take note of the success the Japanese have had in this regard. As we know, many of their early computer products, like those of today, were copies of US hardware. However, important distinctions lie at the root of Japanese success. Japanese electronic firms stress capital investment, timely response to customer desires, and making quality enhancements to the original design. These market-oriented traits are not the hallmarks of the Soviet approach to this industry.

Reverse engineering a complex modern microprocessor has proved to be more difficult than the Soviets had originally anticipated. The silicon flakes that constitute today's computer chips contain increasingly greater numbers of electronic components. More than 10 times the electronic circuitry of the 30-ton ENIAC of 1946 is now contained in a single microprocessor a fraction of an inch in size. Simply to display the electronic paths of this tiny device, with circuit diagrams readable by the unaided human eye, requires the space of a gymnasium floor.[44] The task of replicating such complex microcircuitry is formidable enough when tackled in a sequence envisioned by the designer, but to copy the finished device and attempt to recover the logic of the original designer is far more difficult.

Hardware deficiencies in the USSR are further aggravated by the lack of computer-aided design and microprocessor fabrication technology available to Soviet scientists. This shortfall is due, in large part, to the embargo on such technology by the Department of Defense.[45] Unable to create circuits by minimizing the distance between internal connections, the Soviets are forced to locate similar functions together, regardless of

the resultant inefficiencies in circuit design. Even if equipped with sufficient technological capital and staffed with sophisticated personnel to make replicas of Western computer technology, the Soviets still face a gap. The approach of reverse engineering attempts to bypass the engineering principal of "paying your dues on the way up the technological ladder," as Carl Hammer expressed the point. In other words, experience and insight are gained primarily by doing the work rather than copying it. That, of course, takes time, and when you are coming from behind as the Soviets are and the pace in the field is accelerating, the one thing lacking in an attempt to close the gap is time.

It has been suggested that Soviet gigantomania creates a basic antipathy to miniaturization. The drive in Communist regimes to always build big—everything from dams and factories to planes and tanks—is perhaps a psychological barrier to microchip production. Typical of the cynical, reticent, and revealing humor coming from Communist countries is the often said jest among computer manufacturers that the Soviets will soon announce production of the world's largest microchip!

Because of the short supply of high quality semiconductor manufacturing equipment and the high capital cost of such devices as the x-ray etching machines and electron and laser microscopes, the Soviets have thus far avoided the manufacture of chips at the high end of the technological scale, for example, large scale integrated circuits, very large scale integrated circuits, and complementary metal-oxide semiconductor fabrication techniques (with the possible exception of custom-made materials for military and space projects).[46] Even with such a capability, the evidence strongly suggests

that the Soviets lack the depth in experienced CAD/CAM personnel to make optimum use of the technology.

The Soviets appear to be learning these lessons now. In 1986, Anatoly S. Alexeyev, Director of the Headquarters of the Siberian Academy of Science Computer Center, said that the "make or take" decision of the late 1960s still haunts the Soviet computer industry.[47] In addition, the industrial base necessary to make computers has not fully developed. Because of traditional Soviet bureaucratic methods, it is fragmented among four ministries and three government committees.[48] Alexeyev uses these explanations to account for the Soviet lag in computer technology.

As if to signal the importance of this situation, by 1980, Gury Marchuk, computer scientist and former Director of the USSR Academy of Sciences Computer Center at Novosibirsk, was nominated Deputy Prime Minister and Chairman of the General Headquarters for Acquisition of Western High Technology (GKNT).[49] The nomination of a computer scientist to this prestigious position indicated the Soviet leadership's concern with the "computer gap" and their determination to close it. Nonetheless problems remain, and although computer technology moves ahead rapidly in the West, little comparable change has occurred in the USSR.

The discussion of computer hardware would not be complete without a word on "peripherals." This generic term accounts for all the specialized devices that perform such functions as mass data storage, printing, and communications. The chip is an essential component in all of these machines today, and in the West each has provided a niche for firms specializing in their manufac-

ture. This added complication only serves to aggravate the central planning tasks that already plague the Soviet computer industry and further contributes to their low status in the field.[50] Again there is a generic principle of industrial technology at work. The trend in Western manufacturing and industrialization has always been towards increased specialization, complexity, and differentiation. Inherent in this trend is the fact that a relatively small number of similar production processes, in this case chip production, are introduced to a large number of industries, in this case for not only numerous peripheral devices but also a host of products that incorporate chips, from automobiles to video recorders. In the West, all of this market activity advances and finances the basic business of manufacturing computer chips in their many guises. It also affords the systems engineers a wide variety of products from which to choose when designing a computer-based system.

As for supporting and maintaining the computer hardware that exists, the Soviet record would make computer devotees and managers in the West cringe. Dr. Grace Hopper, a leading US computer specialist, points out that a serious lack of technicians haunts the Soviets in their efforts to move ahead with computerization.[51] Velikhov noted in his account of the Soviet experience with calculators that in the USSR no one knows how to fix calculators nor are batteries usually available. The problem of servicing technology is not peculiar to computers, as the situation with the automobile in the USSR attests. Such service deficiencies have become the target of one of Gorbachev's reforms in the domestic service sector of the economy.

5. Software

REGARDLESS of the speed or memory capacity of a computer chip, it remains a useless maze of electronic circuitry until a person directs it to function. At the level of today's technology, man directs the computer through specific written instructions called "programs." Such written instructions, known in general terms as computer software, take many forms, depending upon the technical level of the use and the task the software is designed to accomplish. Software has surpassed hardware as the driving force behind successful computer systems[1] and is another area in which the Soviet record is one of sub-par performance when judged against that of other leading industrialized countries.

Software Types

Ultimately, all instructions given to the computer must be translated to machine language, that is, to a binary (i.e., one or zero) notation. Actual functioning based on the instructions provided must follow the mathematical rules of Boolean algebra, a well-defined set of logic tables in which all possible outcomes are expressed in terms of True or False—readily represented as a one or zero. Thus, Boolean algebra imposes strict logical discipline on the computer's operation—a characteristic for which the computer is renowned. The computer's electronic circuitry (hardware) duplicates the

logic tables of Boolean algebra—each of which can be used with the appropriate software command. Given the enormous capability and low cost of today's computer hardware, however, these mathematical constructs are largely invisible to the user. Most users are completely unaware of such complex mathematical procedures when they use a piece of commercial software designed to be "user friendly. Thus, it is not necessary to be well-versed in Boolean algebra or binary arithmetic to be an effective user of a computer.

Industry, educators, and users divide software into two broad categories—systems software and applications software.[2] Systems software is designed to render routine the myriad tasks associated with the computer's internal operation. Such functions as control of the keyboard, video display, disk drives, and printer operation would be extremely tedious for the user to accomplish without good systems software. Primarily for this reason, systems software is relatively well standardized. As the microminiaturization of hardware progresses, many of these functions are designed into the chip's circuitry. This link of hardware and software technologies is important because it enables the instructions of the operating system to be executed with minimal need for translation—thereby attaining higher levels of efficiency (and speed). Such an interrelationship underscores the increasing complexity of computer systems and also highlights the complexity of the USSR's problem in coping with state-of-the-art computer technology. In this particular facet of the Soviet computer problem, we should note that limitations in hardware capability translate into limitations in software capability as well.

To use the computer to solve problems—scientific, engineering, statistical, financial, or recordkeeping—

programmers have developed a variety of computer languages. When computer programs are written in these languages to accomplish a specific task, the ensuing set of instructions is referred to as application software. At the present time, hundreds of computer languages exist. Computer languages are generally referred to as higher level or lower level languages. In general, languages at the higher end of the spectrum are readily understandable by the user and frequently use common English words or phrases, thus meriting the designation "user friendly." At the other end of the spectrum is machine or binary language and its cousin hexidecimal language—commonly used in some form by system programmers. Languages at the lower end of the spectrum contain commands that do not convey self-evident meanings. Training and experience are required for the user to become proficient in such software, just as they are necessary to gain fluency in a foreign language.

In the early years of the computer industry (1950-1970), computer hardware was the major cost associated with a computer system. But as figure 6 on page 78 shows, the cost of the electronic circuitry required to perform a million operations per second has steadily declined for computers of every type.

By contrast, the cost of computer software and the intellectual capital that it represents have steadily increased. Computer and information systems experts commonly place the ratio of software costs to hardware costs at 3 or 4 to 1 and rising. The software industry in the West is strong and growing; sophisticated US software programs lead the world market with a 70 percent share.[3] The number and variety of software products available in the West are simply too large to list. (Of the complementary technologies of hardware and software,

the former is the more mature and definable technology in terms of the quantifiable measures used to evaluate it.) Nonetheless, computer software is a problem for the West as well as the East. We need only reflect on the 1987 introduction of IBM's Personal System/2 line of computers to illustrate the problem. Advances in hardware capability and affordability dictated the marketing of the new hardware a year before its systems software was even scheduled to be available and in the absence of applications software capable of capitalizing on the new hardware.[4]

The link between hardware and software is also a problem for the Soviets, as Soviet authors M. N. Bukharov and A.Y. Oleynikov note in discussing the design of software to support realtime automated computer systems:

> A second issue of no less importance that increases the time of development of automated systems is that most of the work on debugging can be done only after the hardware used in the system has been fabricated and adjusted.
>
> The programmer often does not have access to the entire set of hardware needed for debugging the software being developed. This necessitates the development of subprograms, dummy drivers and expensive software and hardware emulators of the missing devices.[5]

From these thoughts we can see that the Soviets realize that software development is closely linked to the backward state of their hardware. It is difficult to progress in one area without comparable capability in the other. Let us now examine in more detail the nature of the task of software production.

The Skill

The writing of software, despite periodic efforts to systematize and standardize its creation and

maintenance, remains predominantly an art form. Creativity and experience on the part of the programmer are the keys to a successful application. As Dr. Edger W. Dykstra, Schlumberger Centennial Professor of Computer Science at the University of Texas, Austin, wrote of software in the 25th anniversary edition of the German magazine *Elektronesche Rechenanlagen,* "the mechanism [software] being abstract, its production is subsumed in its design. In this respect a program is like a poem: you cannot write a poem without writing it."[6]

The Soviet Way

The consequence of the Soviets' policy to replicate the computer systems of the West rather than design their own has been even more damaging in the production of software than of hardware. The same "make or take" decision that charted the course for Soviet hardware development and acquisition was, in part, motivated by the initial easy availability of billions of dollars worth of IBM software that had already been developed for use on IBM computer systems. As with Soviet hardware, fewer manpower resources were initially required to simply expropriate Western software. But long-term problems have surfaced. First, the experience base necessary for further evolution and progress in software engineerng was not established. Secondly, the Soviets did not anticipate the dominance of English-based computer languages when they elected to follow in the footsteps of IBM. This latter development, coupled with the rapidly changing nature of software, has presented a "language barrier" to the Soviets. In the absence of software developments elsewhere, the efforts of American progâmmers are oecoming a *de facto* standard for the world—to include the USSR. As is

the case with hardware, the Soviet Union has been forced to rely on Western software to an extent in excess of what it originally envisioned.

As a result of all the factors outlined above, the USSR does not have a reputation for producing useful software of high quality. In indirect and often subtle ways, the Soviets themselves are coming to realize their software deficiencies. Recently, a group of three Soviet educators and scientists collaborated on an article for the Soviet publication *Kommunist,* entitled "Man's Capabilities and New Technology." Their purpose was to suggest ways to accelerate the USSR's scientific and technical progress. In the course of their discussion they gave considerable weight to USSR computer systems:

> As computers develop, their functions are increasingly changing from data input, processing, and retrieval to a dialogue with man. It turned out, however, that many computer programs were poorly adapted for this function [the ability to dialogue is not included in software requirements]. Comprehensive attention is being drawn to the inconvenience of using existing computer software systems. Whereas, previously the purpose of the program was to control the computer, now, as aptly stated by a scientist, the purpose of the machine is "to implement our own programs." In other words, . . . now the attention is directed at human labor. This has necessitated the development of a system adapted to man. . . . The possibility of providing the user with proper advice is still the most important feature of perfecting interacting computers, expert systems above all.[7]

It is revealing that Soviet academics and scientists are publishing such ideas in 1986. This short passage highlights several important points. We can see that the Soviet intelligentsia is concerned about the policy aspects of what we call "user friendly" systems software. Notice also that they decry the absence of "requirements" for producing software aimed at facilitating

the man-machine dialogue. Again we can see how limited and cumbersome a central bureaucracy, intent on planning all industrial activity, is at unwittingly retarding development in this key area of computer application.

And how does the Soviet situation contrast with the situation in major industrialized democracies? The answer is best summed up by Robert C. Goldstein in his 1985 text, *Database: Technology and Management.* Speaking about the large lines of user friendly data base software in the West—software capability much coveted by the Soviets—Goldstein says, "Whatever the current state of this field [data base software] may be, it has reached that position through being pushed by users with problems rather than through being pulled by researchers enamoured with complex technology."[8] In this declaration we see the hand of the marketplace pushing quality software applications. Recalling ideas fundamental to cybernetics, we also see an emphasis on feedback mechanisms from users to producers at work. And finally, the notorious openness of the West's computer industry—the job hopping, gossiping, and professionally motivated "one-upmanship"—propels the advance of quality software at a rapid rate.

Let us return to Soviet software. Their larger and more complex systems contain program modules of between 2,000 and 3,000 lines of code. (A program module is a segment of computer code that is intended to accomplish a single function. For example, a module can be designed to collect and store data from a sensor or control the movement of a radar antenna in one direction. In common practice, many modules are strung together to form a complete system.) By contrast, it is not uncommon for modules in Western programs to contain from one to three million lines of code. For

example the AT&T communication system consists of 50 million lines of code, of which 20 million are not redundant. Although hardware capabilities are a factor in limiting the size and scope of a program, complexity of code and the ability to test and check the program are also factors. The difficulty in validating (thoroughly testing and checking) software is said to increase by the power of two as a function of the size of the program. Rather than cope with the complexity and magnitude of this validating problem, the Soviets tend to design systems that rely on the biological computer, man, as the primary means of enhancing the scope of an automated system.[9]

The most recent and telling report on the state of the Soviet software industry is contained in the Foreign Applied Sciences Assessment Center Technical Assessment Report 2020 of 31 July 1984. This report, authored by eight international computer science experts, makes the following observations on the subject of Soviet software:

> Overall, the Soviet computer science literature is disappointing. Its average level in almost all the areas covered in this section [software engineering] is considerably below that of the comparable US literature, a surprising fact in view of the excellence of Soviet work in other related areas, especially mathematics. Few ideas not familiar from the US literature are encountered, and where systems, for example, programming languages, are novel, they seem contrived and ineffective. Although most of this lag must derive from the generally inferior equipment that had been available to Soviet computer scientists, it is also striking that the potentially great theoretical strengths of Soviet science do not seem to have been effectively deployed.[10]

Poor software engineering is a sensitive subject to the Soviets themselves. As evidence of how badly the

USSR has fared in this competitive environment, consider the following facts:

- No Soviet computer language is used internationally, and few are used even within the USSR. Instead the Soviets have chosen to employ Fortran, COBOL, PL/1, and APL – all high-level computer languages expressed in English words.
- Soviet authors tend to prize elaborate mathematical formalism, regardless of its efficiency or elegance, when selecting alternative solutions to software applications. Consequently, we commonly see Soviet systems composed of in efficient computer code processed on less capable hardware. The net result is a suboptimal computer operation.
- The quality of Soviet software is low. Most programs lack a mechanism for users to provide feedback. Furthermore, software tools widely available in the West – such as program text maintenance utilities, document formatting routines, and debugging systems – are not readily accessible to the Soviet user.[11] Such practices reduce the efficiency of Soviet programmers in producing applications software.

More recent evidence also bears out these findings and indicates that little progress has been made since 1984. As Deputy Director of the US Information Agency's 1987 cultural exchange program with the USSR, entitled "Information USA," Mr. John Aldriedge conducted liaison visits to the USSR. During one such trip he obtained a copy of the 1985 "USSR Computer Programming Olympiad for High School Students," a 95-page booklet reporting on the contest. The competition and the problems were explained in detail in the

first 26 pages. This section was followed by 32 pages of award winning solutions to the problems, with the remainder of the text devoted to solution explanations, critiques, and instructions. Two aspects of this booklet are most striking. First, the problems themselves are all quite simple; the programs read data, accumulate it, test for a range of values, and print a result. Second, because the solutions to this USSR computer programming competition are in the readily readable English of Fortran, even the novice programmer can gain an impression of their relative simplicity (figure 8).[12]

```
C
      READ 100,N
      PRINT 100,N
      DO 2 I=1,10
      DO 1 J=1,10
      K=N-(J-1)-(I-1)
      IF(K.LT.1) GOTO 2
      IF(K.GT.9) GOTO 1
      M=100*K+10*(J-1)+I-1
      PRINT 110,M
    1 CONTINUE
    2 CONTINUE
      STOP
  100 FORMAT(1X,I2)
  110 FORMAT(1X,I3)
      END

C
      INTEGER*2 A(31)
      READ 100,N,(A(I),I=1,N)
      PRINT 100,N,(A(I),I=1,N)
      DO 1 I=1,N
      IF(A(I).EQ.1) GOTO 1
      A(I)=1
      GOTO 2
    1 A(I)=0
      N=N+1
      A(N)=1
    2 PRINT 100,N,(A(I),I=1,N)
      STOP
  100 FORMAT(1X,I2/31(1X,I1))
      END
```

The two programs shown here can be interpreted as simulating a countdown. Data passing the specified range checks are incrementally altered until the countdown begins.

Figure 8

A typical page of solutions for a high-school Soviet programming competition.

These simple examples bring us face to face with a key issue: the predominance of computer programming languages based in English. A Soviet publication on design management information systems discusses the development of algorithms to assist in that process. The text notes in passing that these algorithms are "implemented in Fortran, PL-1, COBOL, and ALGOL languages, which are included in the software of YeS computers and other Soviet computers."[13] At the machine level of course, all computer languages are reduced to representation in the binary numbering system. The purely mathematical form of the systems program is not subject to cultural bias; indeed, in the early years of data processing machine language was heralded as the first truly universal language. However, as computer systems became larger and more complex, the binary strings of 1s and 0s became longer and harder to manage. Consequently, only those computer specialists devoted to writing compilers or translation programs now concern themselves with the binary coding of computer instructions. Application programs, on the other hand, are subject to cultural bias. Computer-based information systems familiar to us are coded in one or more higher level programming languages. Virtually all these software languages are based on the English language. It is at this point that cultural or linguistic biases emerge: language barriers begin to impede the smooth flow of technological knowledge. We are just beginning to become aware of the scope of this phenomenon, which often lies hidden amongst the complexity of computer systems, and our understanding of literacy. As any elementary French student knows, learning a foreign language is not simply a matter of one for one word replacement (although Russian is more forgiving in this respect than French).

In reality there exists a network of background information which a learned reader must possess to fully understand a sophisticated message. This is a main point in Hirsch's best seller, *Cultural Literacy*. Hirsch reserves his strongest words for communication involving highly technical subjects.

> Advancing technology, with its constant need for fast and complex communications, has made [cultural] literacy even more essential to commerce and domestic life

and

> . . . multilingualism enormously increases cultural fragmentation, civil antagonism, illiteracy, and *economic-technological ineffectualness* [my emphasis].[14]

Thus, creating software in a foreign language, even with the limited vocabularies which constitute computer languages, is not an ideal situation.

Some anecdotes will illustrate just how dependent the world, and the USSR in particular, is on English-based computer programs.

In the fall of 1981 a project manager for a large US computer services company was putting together a project team to complete programming-associated tasks for a major customer. In the course of interviewing prospective programmers for this new team, he met a former Soviet citizen who had previously served in the Soviet Armed Forces as a programmer at a radar site. His experience as a programmer was with the IBM 370 system using COBOL as the programming language. As this former project manager told me, "As long as I posed my interview questions in the form of COBOL statements, he could provide concise and accurate answers. He spoke perfect COBOL and was a very experienced programmer."[15] In a similar vein the predominance of English-based computer software is also admitted by executives at BULL, the IBM of

France: "We at BULL have in the past developed applications in French programming languages, but customers will not buy them. The preference is clearly for applications written in such languages as COBOL, PASCAL, and FORTRAN."[16] These languages, although used in various versions, have become the de facto standard for the industry, thus easing problems associated with maintaining and altering software.

Others also write about the phenomenon of English-based programming languages in the computer industry. As researchers noted in an article discussing the educational programs of the current Soviet computer literacy campaign, "It is one thing, and probably bad enough, for a professional Soviet programmer or engineer to be constrained to write programs in an English-Russian pidgin language. It is quite another to ask a ninth or tenth grader to do the same. Learning to program is sufficiently intimidating for most people without simultaneously having to juggle two natural languages [as opposed to computer languages] and two alphabets."[17] The inefficiencies inherent in this approach to software development often expend valuable resources out of proportion to the gains achieved.

In the light of such a situation, we should recall the fundamental function of a computer-based information system, transforming masses of raw data into usable information. At that point, a product is delivered to the user which is intended to enhance his knowledge. Many would also argue that, in the long run, knowledge and the experience of its use create understanding and wisdom. A primary vehicle for accomplishing the initial stage of this transformation, data accumulation and processing, has come to be the virtually exclusive realm of computer languages and applications software of US origin. This cannot help but exert a leveling effect, a

migration of fundamental problem-solving concepts in this case, on the individuals who must define and translate the tasks identified as data processing applications—be they central planning models or profit margin projections—into instructions that the computer can execute. The languages they most routinely use in that process have come to be a "subset" of the English language. The establishment of even simple commands, such as DO UNTIL or GO TO as compared to DO TILL, MOVE TO, or GO DO, while perhaps synonymous for English speakers, is not necessarily synonymous for those of a different native tongue.

Soviet intellectuals and leaders are sensitive to these issues. For the more conservative and orthodox Soviet leaders, such manifestations merely bear out their initial counsel to avoid contact with the West and develop native expertise in computer technology. However, as the pace of advancement in both hardware and software in the West continues to accelerate, it becomes less and less feasible for the Soviets to start over and design their own software from scratch. Time and resources for that are simply not available. This is surely a point of great concern and much discussion among Soviet leaders who are concerned with how to best close their computer gap with the West. The problems mount.

The Bureaucracy of Software

Gorbachev has made a reputation for himself by speaking more openly with the Soviet people than any Soviet leader in recent times. Many experts suggest that he is, in fact, taking his case to the people in an effort to effect change in the USSR. Overcoming bureaucratic obstinacy, even in an authoritarian regime, is one of the commonly accepted reasons for Gorbachev's methods.

This same bureaucratic intransigence is no less a part of the Soviet problem in applying computer systems to useful purposes.

A useful computer-based information system is the result of a complex process involving a wide range of professional skills. To design a specific information system the development team thoroughly reviews the organization to be served and the attendant tasks to be accomplished. It then identifies areas requiring computer support and defines various major systems and subsystems as targets for computerized support. As the process continues, the team specifies discrete tasks and task elements and begins creating computer software to accomplish or aid in the accomplishment of these tasks. Obviously to do its job correctly, the development team must be privy to a great deal of information concerning the organization and the tasks to be performed by the computer system they are planning. While this issue is a tangent to my discussion at this point, it is certainly an information control matter that permeates the problem of computer usage in the USSR. To date the solution to this dilemma has been to create a stratum of technocrats who are provided with the appropriate privileges to ensure their loyalty. Of course, such an approach is in danger of becoming top heavy as the volume and scope of the work grows. Additionally, there is the problem of training enough qualified manpower, even if the special privileges scheme can be supported. This is just another part of the USSR's problem in this area, but the system has found a way to respond.

In its zeal to rapidly develop the software (and thus stretch its limited supply of trained and reliable manpower) for computer-based information systems, the Soviet bureaucracy has established a faulty incentives process. The Soviet bureaucracy gives recognition in

the systems development process for the number of systems initiated and the number of tasks completed, not for the completion of the system as a whole or for its operational efficiency. Thus, the performance of systems developers and programmers is measured by the number of pieces of the total system that they start to develop and encode. Little concern is given to fitting all the discrete subsystems together or completing an entire subsystem before moving to another task and additional recognition.[18] As we have seen elsewhere, size counts far more than efficiency in the Soviet system (gigantomania). The result is fragmented systems that managers and supervisors must devote additional time, effort, and staff to if they are to realize any benefit whatsoever. Indeed, they often must take extraordinary measures just to keep up any work flow at all. Imagine software in an inventory management system that accounts for raw materials from two of a plant's three regular suppliers. Because the entire system is not integrated, automated information from the two suppliers must be manually input into the central source document. This results in a third set of data, processed in a different manner from either the automated or manual portion. Though technically automated, the entire system requires additional effort to operate. Predictably, those who should be supported by the system find the "old ways" of inventory accounting easier and avoid using the "new automated" system.

There are other signs that software development presents a significant challenge to the Soviets. In May of 1984, V. Myasnikov, Director of the Administration for Computer Technology and Control Systems in the USSR, announced on Moscow Television that while the planned annual value of software production was between 2,500 million and 3,000 million rubles, the actual

value of annual production was 10 to 15 million rubles. He went on to note that computers were only being used an average of 12 hours per day instead of the recommended 18 to 20 hours each day.[19]

The Threatening Aspects

Because computer software is widely recognized as a knowledge-based manpower intensive commodity with a continual requirement for maintenance, it has surpassed computer hardware as the major cost in a useful computer-based system. But the expensive price tag of computer software is not the only obstacle the Soviets face. Computer software is, by its nature, a troublesome and challenging entity for any culture to manage—but especially so for the Soviet mentality.

Novice users of a computer system will readily attest to the limits of the programs or system they have come in contact with. As the user in front of the machine becomes more familiar with a program or system of programs he is using, he will inevitably find flaws and limitations ultimately attributable to the software programmer behind the machine. Many would equate the search for a perfect software system with the quest for the Fountain of Youth: each exists only in the imagination. Soviet policy-makers are especially aware of the inevitable flaws in any software package—a situation that only adds to their woes. Ultimately, everyone must accept the fact that any substantially large computer program, being the product of a fallible human mind (or in many cases the result of a team effort), almost certainly contains errors that can produce unforeseeable and illogical results. Given the present state of the art, computer-based systems are not totally

knowable or controllable—a troubling thought to the Soviet hierarchy.

To fully appreciate this point, we should look at a large-scale computer application, the US Strategic Defense Initiative (SDI). The proliferation of errors in computer software is one of the key weaknesses of SDI. An article in the December 1986 issue of *Discover,* entitled "Will Star Wars Work? It Isn't a Question of Technology," asserts that the "biggest problem facing a comprehensive system is software." The author notes that current computer hardware does not operate fast enough to defeat hostile missiles and warheads in a timely fashion. This weakness is a function of the massive size of the programs required, as well as the operating speed of computer logic circuitry. Although a solution to the latter problem—purely a hardware issue—is in the offing, software complexity remains a challenge. The following words from the *Discover* report on SDI are indicative of software problems peculiar to many large computer systems.

> The size and complexity of this program [SDI] dwarfs by many orders of magnitude anything ever attempted. Computer programs are notoriously prone to bugs—unpredictable results from seemingly routine instructions in unanticipated circumstances. It often takes longer to de-bug [correct] programs than to write them, and some bugs don't show up for years. One study by AT&T, which uses complex programs to manage communications systems, discovered 300 serious errors for every thousand lines of computer code.

The Soviets, in particular, find this risk of error intolerable. Their tradition of coping in a threatening environment by means of a risk-avoidance behavior is inconsistent with this situation. Furthermore, this situation makes it tempting for Soviet leaders to continue their policy of relying on "man in the loop" systems

rather than weathering the transition to new technology.

The Soviets also take a dim view of other attributes of computer software. Mid-level bureaucrats fear the false sense of security and power that sophisticated software systems give their users. A US incident will provide a useful illustration of this danger. The Tower Commission, in its analysis of the alleged "Arms for Hostages" activities conducted from the offices of the US National Security Council, reported that those involved in the suspected scandal used the IBM Professional Office System software, PROFS. PROFs offered security for classified information and the apparent ability for users to purge the system of documents and files that the user wanted to destroy for whatever reason. However, many users of this system were unaware that every document or file created on the system was automatically stored in a permanent archive.[20] Soviet bureaucrats, whose survival depends upon carefully protecting themselves from intrusive inspecting, would certainly find such a feature unacceptable and disconcerting.

The creation of software is a process that encourages individual initiative and creativity. Most successful computer programmers, we have come to realize, have an artistic temperament in addition to a strong background in mathematics and scientific reasoning. Free market forces encourage creativity and innovation, resulting in an avalanche of software products that address a wide variety of needs and functions. This creative ferment, especially in the United States, promotes more and more activity from individuals with a knack for such work. But however prolific the output, the demand for talented writers of software exceeds the supply. Companies are offering salaries of up to $75,000 and have been forced to recruit abroad to meet their needs. The US Government, with salaries restricted by

Federal pay scales and unable to retain qualified programmers, is increasingly forced to use outside contractors.[21] In brief, empirical evidence strongly suggests that the free market environment of the West coupled with readily available and inexpensive computer hardware fosters skills far superior to those seen in the collective environment of the East. In the USSR, Soviet leaders are uneasy about the individualization and decentralization that the computer, especially the "personal" computer, promotes. Thus, they steadfastly adhere to their doctrine of the "kollektiv" use of computer technology.[22]

In the software arena we encounter the progressive symbiosis between man and machine. Expert systems and artificial intelligence are in the avant garde of attempts to create a machine that mimics man's mental functions. While this is a "hot topic" in the R&D programs of all major universities and corporations concerned with information technology, the USSR shows little activity in this area. Thus, it is logical to believe that while Soviet software technology is at least a decade behind the state of the art, it will fall even further behind as technology advances in the West.

6. Education

THE PEOPLE who create, operate, and use computer-based information systems are key to the success or failure of such systems. The principle that human resources are the key to success in any organization is a management and leadership tenet with universal application—true on both sides of the Iron Curtain. Furthermore, the view that "computer people" are somehow different from other employees is also a popular perception that is not without some validity. In this chapter I will discuss personality and skill traits characteristic of "computer types." How such personality types flourish in the West and encounter obstacles in the USSR is another dimension of the Soviet computer dilemma. I also will review current Soviet programs intended to develop a more computer literate populace in that country.

The Western Computer-nik

The rapid development of computer hardware and the wide range of uses to which computer systems have been applied have attracted a unique type of entrepreneur and career specialist to the computer industry. Initially, World War II government research and development programs gave birth to the computer. Subsequent early advances in computer technology were indirectly financed by commercial applications of computer technology.[1] For example in the United States, the

annual domestic market for the computer industry in the late 1980s is from 60 to 70 billion dollars. This is a major source of investment capital and R&D funds for the continued growth of the industry. Among the entrepreneurs who have developed and continue to expand this market are such men as H. Ross Perot, Kenneth Olsen, Jimmy Treybig, and Steven Wozniak. Their approach to business has been viewed as unconventional and revolutionary, especially when compared with their predecessors of the Industrial Revolution. Terms used to describe their characteristics include freewheeling, relaxed, laid-back, innovative, flighty, off-beat, and inspirational. In short, those who have borne the risks in the rapid development of chip design, manufacture, and computer systems evolution in the last two decades are judged unique in the business world.

The methods of managing and leading major Western computer firms have been key factors in the development of computer systems that are properly configured. In the process the computer industry has given rise to several specialized professions. These vocations include computer operations, programming, and analysis, just to name the principal ones. Studies have identified a definite personality profile for the individuals in these new professions. These studies show that those successful in computer-related tasks are of above average intelligence, able to tolerate stressful situations for periods in excess of a week, adaptable to rapid change, able to organize paperwork and maintain that order, assertive (with a tendency to be arrogant), methodic yet innovative, and gifted with a keen sense of humor. There is also evidence that interacting with computer technology fosters these personality traits.[2] Additionally, computer professionals are notorious for their

mobility in the workplace. The quest for professional challenges as well as higher salaries frequently takes them to new assignments.

These human factors have been key to the remarkable growth of computer-based systems in the West. How the leadership and management of the computer industry develops its human resources is as important as the hardware and software their companies sell. What Soviet leaders and planners must do to create a comparable reservoir of computer literate talent in the USSR is a large part of their problem and a significant contributor to their computer gap.

From February to May 1987, the Industrial College of the Armed Forces conducted the Defense Industry Studies phase of its curriculum. As a member of the Telecommunications and Information Systems Seminar, I had the opportunity to attend briefings presented by the top management of more than 15 leading companies (some multinational) directly involved in the development, manufacture, and use of computer technology and related services. Among them were representatives from IBM, AT&T, Digital Equipment Corporation, Thompson C.S.F., and ALCATEL of France. In every case, these companies placed the utmost importance on their human resources—their brain power. Some of these companies were born out of the Western computer revolution. Their founders are all very conscious of the value of the creativity and initiative of their employees and have established company policies designed to foster the same. From these corporations' policies, I have compiled the following representative list of personnel practices adhered to by the most successful and innovative companies involved in computer technology.

Personnel policies from high tech computer corporations:

- Treat people with respect.
- View change as a constant.
- Allow employees the freedom to fail.
- Use feedback loops in all facets of the organization (application of cybernetics and systems theory).
- Treat employees fairly, not necessarily equally.
- Promote "open" management—management by direct contact.
- Use electronic mail to bypass the chain of command and reduce intimidation.
- Allow employees a share in corporate success and failure.
- Use a corporate ombudsman to promote quality and fail-safe systems.
- Delegate tasks and decisions.

As we can see, computer firms place strong emphasis on nurturing and caring for their people, as well as on training people throughout their association with a firm.

But where is the source of personnel coming into this industry? How do nonspecialists in other industries manage to proficiently use the products and computer-based systems developed by the leading high-tech companies of the West? The answer to both questions is an unrivaled level of computer literacy in the West and the United States in particular compared to other countries. As recently as 1984, for example, 85.1 percent of all elementary and secondary public schools in the United States had microcomputers for student instruction. In senior high schools the numbers climb to 94.6 percent.[3] However, just as in the business world, the situation is changing so rapidly, it is hard to find current figures

which are accurate. According to Quality Education Data, a research firm, in US schools for grades K to 12 there were 750,000 computers, or one per 50 students, in 1986.[4] Given current trends, this number is sure to double by the year 1990. Furthermore, 1985 estimates place the number of microcomputers available in American colleges at 530,000.[5]

The West's obsession with the computer has created a huge market, which in turn encourages a proliferation of products. For example in the United States, widespread use of computers, both privately and in industry, has promoted familiarity and confidence in the population. The Atlantic Institute for International Affairs, a private research group based in Paris, France, has concluded that more than any other people, Americans are at ease with the idea of belonging to a computerized society.[6] These results, released in 1986, were attributed in part to the fact that 37 percent of Americans attested to having hands-on experience with computers or word processors. As this trend towards a service-based economy with its attendant white-collar office work force continues, this figure will rise steadily.[7]

The widespread interest in personal computers in the United States has spawned phenomenal stories of entrepreneurial success. The legend of Steve Jobs and Steve Wozniak creating Apple Computer Corporation in a garage is probably the most famous of the modern day high-tech success stories. But there are many more, all based on access to computer technology by highly computer literate people. Douglas Becker (a high school graduate who was "into" computers and laser technology), along with four friends, devised a computer and laser technology process to store and retrieve up to 800 pages of information on a plastic wallet-size card. Their

process is being adapted to the storage of detailed medical information, which will be read via a code by authorized health-care personnel for Blue Cross and Blue Shield subscribers.[8] Just imagine an emergency medical record that each individual can carry in his wallet—an idea of great use in countless situations. Then there is the case of Wilton H. Jones who, in 1982, developed a word-processing program for personal computers. His product, Multimate, soon became an industry standard and made Jones a millionaire.[9]

All these success stories occurred, at least in part, because the entrepreneurs were computer literate and the necessary computer hardware and software were readily available. This is not to discount the role of human genius in the creative process. However, it seems fair to say that even Einstein, the renowned nuclear physicist, would not have arrived at his insights on relative motion had he not lived and traveled in an age of locomotive trains—a vehicle that clearly demonstrated the concept of relative motion and time. In other words, there comes a point when even the most creative minds must be augmented by material resources if they are to realize their potential. Clearly, the proliferation of computers in the West provides an ample catalytic resource for creative potential.

Before moving on to examine Soviet efforts to broaden the "computer horizons" of its population, we should reflect on a subtle but important facet of the Western computer spirit. Give a Westerner a computer and a modicum of instruction in its use, and within minutes or hours this person will begin to experiment in alternative ways to elicit the desired response from the machine. The aim of this "rebellious" practice is to either "outsmart" the system in order to save time and

effort or to expose the system's weaknesses and flaws as soon as possible so they can be avoided and corrected. One benefit of this behavior is the steady stream of feedback to the developers of computer systems, who are then able to improve their products and offer yet more services to the consumer. I invite everyone to verify this from either his own experience or by observing others. This "beat the system attitude" is the way in which the individual independence of Western society complements and spurs advances in computer technology.

Soviet Computer Non-Literacy

As we have seen already in our inspection of the Soviet computer culture, a high priority of all the Soviet leaders who discuss this issue, from General Secretary Gorbachev to Komsomol Central Committee Secretary Aleksandr Zhuganov, is the enhancement of computer literacy in the USSR. How the Soviets are going about this and the results they have achieved are a key factor in completing our study of the USSR's computer gap with the West.

The Soviet challenge in its transition to a computer literate society is one of enormous magnitude. Anatoly P. Aleksandrov, President of the USSR Academy of Sciences, has compared it to the campaign to develop literacy in Russia after the Revolution of 1917.[10] Soviet officials refer to the current program as a "second literacy" of major importance to the acceleration of their economy. Nonetheless, the Soviet record is one of repeated delays in the achievement of their goals. There are roughly twice as many elementary and secondary school-age students in the USSR, 90 million, as compared to the United States. In March of 1985 the Politburo

announced that it would have one million microcomputers for use in the nation's 60,000 secondary schools by 1990.[11]

While desiring to raise the level of popular acquaintance with the computer in their society, Soviet leaders are markedly cautious about their approach to the task. As recently as 11 September 1984, a translation of a *Uchitel'skaya Gazeta* (Teachers' Gazette) article on a plan for mass computer instruction in Soviet schools appeared in Western sources.[12] At that time Yevgeniy P. Velikhov, Vice President of the Soviet Academy of Sciences, announced that Andrei P. Ershov, also of the Academy of Sciences, had been placed in charge of the effort to introduce personal computers in secondary schools. The ultimate goal of this program was to equip Soviet youth with the computer skills and knowledge that would make them more productive workers in the Soviet economy. In the context of the information age, the Soviets see computers as becoming increasingly commonplace, especially as a controller of machine tools.[13] However, noticeable by omission is any mention of using computer technology and training to improve management and data processing tasks.

To accomplish this goal, the Soviet computer literacy program is being conducted on two levels. The first level is a 160-hour introduction to computers and computer programming – 60 hours of teaching time and 100 hours of exercises in computer laboratories. This instruction will begin at the ninth grade level. The second level of the Soviet computer education program will be more in-depth study of the same subjects at the tenth grade level, presumably for students who have demonstrated a natural talent for the subject in the first level of instruction. This is a tacit acceptance of the validity of the notion of a computer personality type. The second

William Mills, Montgomery County Public Schools

Soviet educators visiting the United States in December 1986 listen as Dr. Michael Haney (left) and Ned Johnson (at computer) describe the computer laboratory at Montgomery Blair High School in Silver Spring, Maryland.

level of study will consume 80 hours of classroom time and 300 hours in the school's laboratory. Ershov commented that by the year 2000, one million students should have completed this program. Once this program is underway in the secondary schools, Ershov feels that a number of new computer specialties will be required in occupational-technical school training. However, Ershov was more cautious about discussing a timetable for this program.

At regular intervals since 1984, high Soviet officials have been quoted supporting Ershov's computer literacy plan. In January of 1985, academician Yuri V. Gulyayev, commenting on the USSR's computer modernization program, endorsed the new program and

referenced the Politburo's approval of it, saying, "A completely new level of literacy is required from the population in order to acquire the ability to make correct and efficient use of computer technology."[14] Then, in November 1985, Deputy Minister of Education in the USSR F. Panachin spoke out on the subject of computer use in schools. He summarized and updated Ershov's original program announcement of 14 months prior with minor modifications. Panachin, discussing the problem of training teachers for this new program, pointed out that 20,000 teachers were already in training, with an additional 70,000 slated to attend short-term courses in the summer of 1986. Panachin also predicted that in the "not-too distant future the school computer will be used as a means of teaching mathematics, physics, chemistry, biology, and other subjects." Again the emphasis is on science and no mention is made of using computer systems for administrative or data processing tasks.

A glimpse of a showplace Soviet school that is implementing this program during this same period of time is revealing. Boris Goldenberg is the headmaster at Moscow school 1140 in the northeastern part of that city. His assistant is Sergi Efimov. School 1140 is a showpiece for visiting reporters writing about education and science in the USSR. The school has 900 students, grades 1 through 10, and 16 Yamaha (Japanese-made) personal computers and an Edinaya System 1033 (comparable to an IBM 360 mainframe computer) to support the computer literacy instruction there. In addition to mandatory classes on computer programming for the 9th and 10th grade students, these machines support computer-assisted classes in mathematics and spelling. Only a few select students will actually receive instruction

L. Smolensky, *Pravda*

First-year students in computer and information science at Special Vocational-Technical School No. 13 in Rostov-na-Donu, April 1987.

on a computer; the majority must make do with textbook instruction on how the systems should operate. During the tour of his school, the headmaster pointed out that scientific workers from various institutes were busily at work in the school writing new educational programs for the students to use on the Yamaha computers.[15] By contrast, the problem for US teachers is quite the opposite. With more than 7,000 educational programs to choose from, for US secondary teachers the problem is one of learning what is available and how to integrate it in the curriculum.[16]

The reader should note that school 1140 is one of the exemplary schools in the Soviet capital. Awareness of the backward conditions and limited instruction in their homeland perhaps explains the bewildered looks on the faces of the Soviet officials viewing current US high school computer instruction programs. The Soviet officials must be mindful of the conditions in their

country, where a recent 45-minute television special characterized the technical equipment provided at Soviet vocational training schools as "out of date."[17]

As in Moscow school 1140, shortages of equipment and software are such a major problem for Soviet institutions that in their literature (Teachers' Gazette) they frequently discuss the "computerless method" of bestowing computer literacy on students.[18] Under this plan, educators believe that the shortage of computer hardware will not prevent students from "mastering the theoretical, cognitive part of courses on information science and computer technology. [Students] will be able to perform practical exercises using programs on a microcalculator."[19] This is all too typical of the Soviet approach to its computer literacy program in the late 1980s. The overwhelming impression is one of make-do facilities that limit what the CPSU advertises as a national computer literacy program. And even in Moscow itself, officials are becoming impatient with the pace of educational reform vis-a-vis computer literacy. This sentiment is evident in the words of Boris Yeltsin, First Secretary of the Moscow CPSU, prior to his removal from office. In an address at Moscow's 26 August 1987 pedagogical conference, Yeltsin observed that Moscow's school graduates enter labor collectives "lagging greatly behind life" and characterized the situation in the "majority of Moscow's schools" as "stagnant." Computer skills led the list of shortcomings identified by Yeltsin, who leveled criticism at students and teachers alike.[20]

Training the Teachers

Readers familiar with planning and conducting training and education programs will be sensitive to the preliminary work that must take place before the first

student is trained. Instructors must be trained themselves, materials prepared and tested, programs established, and policy decisions made concerning what of the "old" must be slighted or removed from the existing program to make way for the "new material." All these areas have presented challenges to the Soviets. Their professional literature is ripe with discussions concerning them, and despite the national policies that have been laid out, problems abound.

The USSR's needed information science teachers have been recruited from the ranks of existing mathematics and physics teachers. In the summer of 1985, a crash training program was launched for those selected to spearhead the nation's computer literacy campaign. As with any pilot program there were difficulties – promised workbooks and textbooks were not completed, schedules were not met, and the hardware shortages continued.[21] Additionally, there was much concern that the new information science teachers should not disguise from their students that they (the teachers) were learning the subject simultaneously with the classes – the notion of the instructors' credibility and "face" was deemed of utmost importance in this new endeavor.

The official reaction to this program as attributed to its leader, Ershov, is revealing.

> The situation is ridiculous. . . . People are dropping with exhaustion from overtime work in organizing the retraining of a flood of teachers. Meanwhile, the equipment in the computer laboratory consists of twenty MKSh-2 calculators. Even these are on temporary loan from Irkutsk School No. 42. Nevertheless, 1,500 teachers must be trained; 500 of them in the fundamentals of information science and 1,000 in the use of computers in the schools.[22]

To assist the new computer science teachers, a new column was added to their professional magazine,

Uchitel'skaya Gazeta (Teachers' Gazette), entitled "Osnovy EVM—Vsem, Vsem, Vsem!" (Computers Teach to Each, Each, Each! or more idiomatically, Electronic Computer Fundamentals for Everyone!).[23] Despite formal changes such as in publications of the Soviet Teachers' Gazette, the fact remains that there are too few teachers with too little training to produce the desired results. This is another consequence of the Soviets' late start in the field of computer technology.

In Sum

An ample supply of well-trained and motivated computer literate workers is key to the effective and inevitable maintenance and growth of computer-based systems. The development of such human resourcces requires appealing to the right type of people and sound, well-staffed training programs. The Soviet Union will have difficulty with each factor in this formula. Human characteristics that spring forth in those involved in computer systems development are generally shunned by the Soviet system. Hints of problems in providing the needed incentives for such workers can be seen in Gorbachev's speeches that touch on computer technology issues. In these addresses he goes routinely out of his way to cite examples of young Soviets accomplishing great feats in this and other high-tech fields by working "selflessly and devotedly. They did not ask questions about salaries or work schedules."[24]

The issues of incentives and education, or training, are in themselves significant enough to the Soviets, but to this list must be added the problem of scale. To employ computer technology on a national level to a degree that will make a substantial difference will require millions of people. The statements of Soviet

leaders regarding their computer literacy program show that at least at the training level, they realize this. However, once the new computer literates join the work force a new problem will emerge—how to ration the limited supply of preferential treatment afforded the privileged workers. Under the existing Soviet social system, those with the capability to access sensitive computer systems must be afforded special rights or incentives to ensure their loyalty, even if those incentives offered are not ideal. As the leading Western computer firms have learned, the way to the top, and the way to stay on top, is to take care of human resources first.

7. Prospects

FOCUSING ON THE CHARACTER of the USSR, and the surprising inability of that nation to cope with modern computer technology, is a timely topic of increasing importance. In a 1983 article I suggested that the proliferation of computer technology would necessarily alter the ways of the Soviet Union—its institutions and procedures—because the use of computer technology, particularly in widely distributed personal computing systems, affords a significant degree of freedom and initiative to the user. I believed that the Soviet authoritarian model would necessarily evolve to a less coercive, more representative (democratic) one.[1] More recent evidence has convinced me that such an idea, while a tempting prospect to Westerners, is naive and indicative of a common trap that we in the West fall into when speculating on the future of the Soviet Union. We consistently tend to think that technological forces and economic leverage can drive the Soviet Union to change—and usually a change that mirrors Western ideas and mores. In fact, all evidence suggests the contrary: the use of such leverage to force change tends to harden the Soviet status quo and arouses their intransigence. For these reasons, my conclusions from this more recent and intense inspection of the Soviet situation vis-a-vis computer technology differ from my previous opinions.

Neither historic precedent nor current trends support a hypothesis in which the USSR evolves in the

direction of the Western societal model. The Soviet system is simply too autocratic and disciplined for such an outcome. To party leaders, the doctrine of Marx and Lenin is a matter of faith comparable to a religion in Western terms. When the General Secretary of the Soviet Union speaks to the party elite, the setting and atmosphere are of a bishop or cardinal delivering a sermon.[2] While Gorbachev has endorsed a modified version of capitalism in small businesses, it would be naive to think the USSR has abandoned its ultimate goal of socialism for the entire world. The "changes" underway in the USSR are merely a "rejuvenation" of the "revolutionary process."[3] These facts are central to the analysis and predictions in this chapter.

Thus far, Soviet watchers, in both America and Europe, have had a poor record predicting the ebb and flow of change within the USSR. Khrushchev's rise to power was not foreseen, nor was his de-Stalinization program. Soviet space and military ventures have repeatedly caught the West off-guard; evolution of their current prolonged manned space flights and their lagging computer usage seem to defy logical explanation by Western standards. In 1986 and 1987 Mikhail Gorbachev announced reform programs that were not widely predicted and remain objects of controversial interpretation, both inside and outside the USSR. Our difficulty in predicting Soviet actions is in large measure an effect of the way the USSR is administered. The small ruling group in the USSR has operated and will continue to operate in secrecy. Often power struggles internal to that group are hidden from the view of outsiders until the outcome is achieved. Nonetheless, in the case of the Soviet computer dilemma we know a great deal. While absolute certainty is out of the question, I believe we have enough hard

evidence, coupled with our own experience of negotiating the transition to a computer culture, to venture some likely predictions of Soviet computerization in the coming decades.

The existence of a Soviet computer gap relative to the West is admitted by experts both within and outside the USSR. In the preceding chapters I explained the historical roots of this computer gap, how the Soviet system contributes to it, the hardware and software dimensions, and the personnel issues. Just as the Soviet dilemma with computer technology cannot be attributed to a single cause or event, no single event or discovery can reverse the trend. Publicly, the Soviet leaders call for an expanded, albeit controlled, use of computer capability in their society. *Given the centrally planned* and controlled nature of the USSR, the West can expect to see some movement toward expanded Soviet computer usage. However, such changes will be slow, dictated from above by the government hierarchy, which parallels the party structure, so that in the process, the fundamental tenet of the Communist party's political primacy will not be sacrificed.

Forces Favoring Soviet Computerization

General Secretary Mikhail Gorbachev, Yevgeniy P. Velikhov (Gorbachev's unofficial personal scientific adviser, heir apparent to the presidency of the USSR's Academy of Sciences, and founder in 1983 of the Department of Informatics, Computer Technology, and Automation), and Boris N. Naumov (Director of the Institute of Informatics Problems, a new department founded by Velikhov) all agree that a Soviet computer "boom" is needed. The Five Year Plan for the period

1986-1990 calls for a national computer network with data bases at all levels of the economy and the training of the school-age generation of Soviets as computer literates.[4] Certainly, the official top-level commitment given to this goal is impressive. Given the authoritarian nature of the Soviet system of government, we would indeed expect such plans to have enormous impact. Nonetheless, we find ourselves wondering why the signs all point to slow progress in the USSR's move towards computerization.

Despite the advent of *perestroika*, changes are not apparent. David J. Smith, traveling in the USSR with the American Council of Young Political Leaders from 30 July to 16 August 1988, was guided through many Soviet complexes. During this period, he witnessed only one installation which displayed evidence of computer technology and automation on par with what he has come to take for granted in the West. Mr. Smith's group, hosted by the Committee of Youth Organizations of the USSR, visited the Academy of Sciences in Irkutsk, as well as factories, hospitals, and schools across Siberia. Although the Soviet desire to impress was obvious, in the area of computer technology there was simply nothing to show—only the hydroelectric plant at Bratsk, with digital displays in evidence, gave a clue of the presence of computer technology.[5]

The Soviet leadership is mindful of the situation also; in fact it is probably embarrassed by it. For decades, the USSR has promised the utopia of Marx and Lenin to underdeveloped nations of the world, not only as the cure for their social and economic ills, but also as the quickest and noblest path to national prominence. Historically it has been an article of faith to Communist ideologues that freeing the worker from capitalist op-

pression is best achieved through maximum use of scientific and technological principles. Nevertheless, the Soviet economy has, of late, stagnated and lost ground to the rest of the industrialized world, faltering in the realization of their own doctrine. The computer, icon of modern scientific and technological progress, represents a prime example of this paradoxical failing. For decades now, the Soviets have neglected to fully use the computer for data processing tasks in education and industrial and governmental planning. This powerful tool, able to magnify human mental ability and facilitate the accomplishment of redundant and voluminous mental tasks, is more often than not underutilized. Meanwhile, computer technology thrives in the non-Communist world. Soviet leaders perceive a genuine need to reverse this negative trend. Making greater use of the computer in the Soviet society would forestall embarrassing criticism from observers of this irony in the Third World.

For the past two decades Western technical forecasters, industrial experts, academics, and government officials have stressed that the world is entering a new age of information technology. They argue that, while national wealth has traditionally depended upon land, labor, and capital as they were applied in the agricultural and industrial phases of human history, this situation is changing. It is said that national wealth will depend upon information, knowledge, and intelligence—the Library of Congress rather than ingots of iron. Of course food, energy, and manufactured goods will still be needed, but the processes that produce food, energy, and goods will increasingly be controlled by computer-based information systems. Facts, procedures, codified experience, and large data bases will

replace land and labor as the new form of power and wealth. The central tool in this information age is the computer.[6]

The fierce competition between the United States, Japan, and Western Europe in the arena of information systems is indicative of the evolving economic trend. Many Soviet intelligentsia, mindful of the dawning Information Age, are envious of the flurry of computer activity they see in the West. For some, the age-old Russian inferiority complex begins to show. Their acute sense of exclusion from the mainstream of computer technology adds to the desire to become more computer literate as a society and participate actively in the world information market. Although, as Soviet management information systems analyst William McHenry points out, the Soviets monopolize this industry within their own sphere of influence.[7]

A final telling sign of the Soviets' determination to reverse their country's fortunes in the field of computer technology is presented in a Rand report on the reorganization of the USSR Academy of Sciences in the computer field. In this report Simon Kassel suggests that the US Strategic Defense Initiative (SDI) has given a sense of urgency to the long-standing Soviet intent to increase the use of the computer. Kassel's hypothesis is based on the timing of the Soviets' reorganization efforts—coincident with President Reagan's speech on SDI in 1983—and the appointment of Velikhov, who was previously involved in pulsed power and directed energy research, to lead the effort to erase the USSR's computer gap. With his experience in technologies closely related to space defense and the use of computer technology, Velikhov, a confidant of Gorbachev, is a logical choice. His appointment is a sign of the importance given to this issue.[8]

Economic stagnation, societal degeneration, internal reforms, concern for national image and prestige, the onset of the Information Age, the advent of the US Strategic Defense Initiative—these are some of the principal forces behind the present Soviet move to employ computer technology more effectively.

Forces Against Soviet Computerization

Several well-documented characteristics of the Soviet experience have worked and will continue to work against the widespread use of computer technology within the Soviet Union. The enormous weight of the history of the Russian people and their national heritage has fostered, and sustains, an inherent conservatism, an aversion to risk, and submissiveness to central authority that have survived into the modern Soviet era. In particular, events of the twentieth century have shown these qualities to be self-perpetuating regardless of technical advances—be they industrial or computer-based. Such national rigidity acts as a barrier to the widespread use of computer technology. Modern computer systems can place unprecedented computational power and access to information at the fingertips of many individual users, even those relatively low in the organizational hierarchy. Such a potential scenario is disturbing to the same leaders that advocate increased use of computers in the USSR. To many bureaucrats, prolific information transfer in the USSR is simply unacceptable because it would eliminate traditional information flows, which create nodes of power, prestige, and influence. These factors combine to form the key to party infallibility and hence political dominance.

Russian interpersonal relations follow a linking pin model: one is simultaneously an equal member of one

group and a dominant figure to another group at a lower level. This hierarchical arrangement of community and job relationships serves to reinforce the authoritarian nature of the society. Personal communication in this society is overwhelmingly personalized and is facilitated by a complex system of nicknames that codify subtle relationships. All in all, the impersonal computer is not viewed as an asset in this environment; its forte is speeding communication, potentially in all directions, while simultaneously depersonalizing the same.

In view of Soviet social patterns, it seems unlikely that computers will ever fit as comfortably into organizations as they have in the West. The Soviets simply do not have and, barring major changes in their economic system, will not have the affinity for computer systems to a degree approaching that of the West. There is little economic incentive for established enterprises in the USSR to modernize their technology. New systems disrupt normal work routines and threaten management's control and security. If computer systems are successfully introduced, they will not benefit individual managers, who are neither equity holders nor recipients of compensatory rewards; indeed computer-based data systems will limit the manager's flexibility and undermine his authority. Many of us will recall management's resistance to computer-based information systems in the West during the 1970s. Change and acceptance of the new technology was brought about mainly by competitive pressures. In the absence of such pressures in the USSR, there is far less urgency to automate the transfer and processing of information. Soviet computers standing idle will continue to be the norm.

For the computer industry in the West and Japan, the market has been characterized by a demand-pull pat-

tern. New applications and requirements for computing power surface each day. Personal computers and support for them are widely available and inexpensive. Annually, availability and usability increase, while costs decline. Thus, usage expands and the user knowledge base increases. Such grassroots involvement in computer technology does not exist in the USSR. There computers are in the hands of a few specialists. Nor is the development of nationwide computer usage likely in the future. Lack of hardware and software limits the opportunity for large segments of the population to gain experience with computers. The situation is a vicious cycle that contributes to a permanently low level of computer literacy in the USSR.

Soviet pronouncements concerning computer technology require interpretation. For example, the Soviet equivalent meaning of "mass production" of computer technology differs from that in the West by two or three orders of magnitude. Also, the Soviets normally exaggerate their claims of processing power and represent the one-time performance of a prototype model as a standard. Soviet talk of the future of computer technology in their country is always cautious and qualified. A close reading of statements by Soviet policymakers on this issue reveals repeated and subtle (almost halting) references to the "collective use" of computer assets. While collectivism is, to Russians, a tried and true concept, its applicability to computer technology is less assured and largely unprecedented. And, finally, public statements issuing from the USSR bespeak a pervasive paranoia, a fear of being passed by the Western computer revolution and its global Information Age.

The Soviet bureaucracy, designed for centralized planning and control, presents another significant

obstacle to progress in computer technology. The Communist system of rule—with its need to directly control the state's economic and political process to the greatest extent possible—has of necessity produced a vast bureaucracy. Stagnant, stable, and inflexible, this entrenched bureaucracy is resistant to change; it has institutionalized the status quo. Here too we find a powerful obstacle to the creation of a national computer network, an idea first introduced in 1964.

Soviet leaders are neither unaware nor insensitive to the way the disadvantages of bureaucracy are magnified in the USSR's form of government. As early as 30 June 1929, Lenin contemporary Nikolai Bukharin, whose writings have been banished in the USSR, published an analysis of the work of the organizational theorist Hermann Bente. Bukharin's essay, entitled *Organized Mismanagement in Modern Societies,* ultimately concedes that bureaucratic problems not only apply to totalitarian collectivism but, owing to the emphasis on centralization of the form of government, are often magnified as the economy becomes larger and the bureaucrats more remotely associated with reality.[9] Nearly 60 years later and in the spirit of *glasnost,* Leonid I. Abalkin, Director of the USSR Academy of Sciences Institute for Economics, had even harsher words for Soviet bureaucracy.

> The weakest point of the [USSR] economic mechanism, first, is that it is oriented toward a purely quantitative build-up in volume of production, whereas today's economy is an intensive-type economy, an economy oriented towards the consumer and toward solving social tasks; second, there is a predominance of administrative methods of management in the existing mechanism. Planning methods must also be changed.

Abalkin concludes:

The struggle against bureaucratism will be a long and complex one, but the process of restructuring will only be completed when we see this evil through to the end. . . .

In other words, this movement will not be a sudden one, and one should not build illusions that everything can be changed quickly. And people, too, must be restructured, and new technology must be mastered.[10]

Soviet leaders have permitted some limited uses of computer technology but only those which do not threaten their norms or alter their system. Supercomputers and mainframe computers have been used for large, centrally directed national programs, such as the GOSPLAN. Motivated by concern for security and international prestige, the USSR will certainly devote the requisite manpower and material resources to maintain its defense and space programs—with an exaggerated reliance on the man in the loop. However, concerns for security will not permit the hardware, software, and knowledgeable work force developed for the defense and space programs to be used in the commercial sector. In the area of the micro or personal computers, the East and West will continue to differ—and differ most markedly. Rooted in the disparity between *laissez faire* capitalism and collective socialism, lifestyles of the two cultures will continue respectively to favor and resist the use of private computers (figure 9).

The Possibilities

Orwellian rule. It is possible the Soviets will use computer technology to enforce strict centralized control of their economy and diverse nation in a manner akin to George Orwell's state of *1984*. At one time A. I. Berg and others predicted that the centralized Soviet state was the natural forum for the widespread application of computer technology. The first GOSPLAN also

Forces for Increased Computer Usage	*Forces Against Increased Computer Usage*
Gorbachev's Reforms	History
International Image	Tradition
Entropy	Nature of Science and Education
Information Age	Bureaucratic Resistance to Reforms
Response to SDI	Shortages of Hardware, Software, and Trained Personnel
Economic Stagnation	Secretiveness
Time	*Time*

Figure 9

Forces increasing and decreasing Soviet computer usage.

revealed a Soviet determination to use computers for detailed centralized control. That this seemingly logical marriage of technology and government has not come to pass tells us that there is a fundamental flaw in this scenario. Furthermore, given the USSR's impressive record in the area of mobilizing its resources to achieve a desired end, as reflected in their World War II experiences or their efforts in space, we have another clue of the friction that this issue poses to Soviet leaders. What has happened?

Some facets of the Soviet paradox with computer-based information systems and their future use of them will be a replay of US history in that field. Originally, Western planners assumed that large expensive complex computers would be treated as an organizational

asset — managed and employed in a central fashion. This approach was the norm in the 1950s and 1960s. But as technology progressed, economic barriers to the decentralization of computer power disappeared. At the same time, advances in hardware and user friendly software minimized the size and complexity of computer systems, thereby allowing a proliferation of discrete localized terminals. These developments reversed former standards for computer usage. In the West, numerous automated tasks have been "pushed down" in the organizational chain and indeed in many cases better data and better results could be obtained by collecting data and accomplishing work closer to the source of the data inherent in the task. Known as source data automation, this technique is virtually taken for granted in the West today.

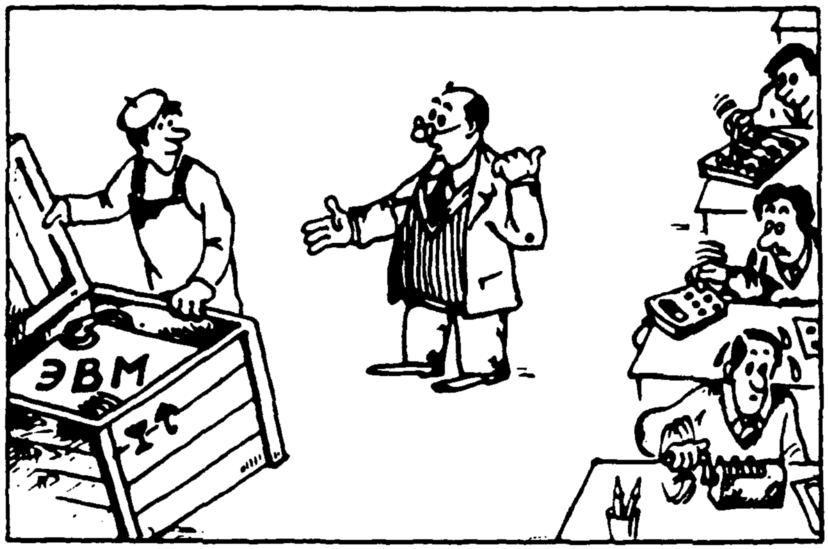
This may be all well and good from the perspective of the functions inherent in a market economy but not so appealing, and indeed not deemed necessary, to the operation and management of a huge nation, like the USSR, committed to a philosophy of centralization. In the case of the USSR, the low-level proliferation of computer use and access is viewed with distrust. Obviously, a national computer network must employ both people and computers in large numbers. Such a situation implies access to and the sharing of information about the system and its processes, information known previously to only a select few. In a system where "information is power," the average Soviet bureaucrat or plant manager will be extremely wary of relinquishing his security to a technological process not well understood by him. So far the record shows that their stonewalling tactics have prevailed.

Besides, the Soviet system offers an alternative computer, man, a tried and true means of managing

information and enforcing social control. Man is a flexible and reliable asset and, by definition, is an employee of the state and must be kept employed. To the Soviets, manpower has many advantages; it is cheap, flexible, and controllable via a wide variety of methods, which can culminate in intimidation and coercion. The Russian tradition of face-to-face, hierarchical forms of communication favors slow but reliable manual systems over computer [illegible]mation in the accomplishment of many tasks. I[illegible] [illegible]n a situation one would be foolish to endure all the problems regardless of culture. Rely instead on man.

Super-communism. If the Soviet leadership could harness an effective computer-based resource allocation system to aid [illegible]ntral planning efforts, economic productivity cou[illegible] [illegible]prove greatly. As we have come to realize, the USSR is, by any standard, a rich and powerful but underdeveloped state. Its natural resources and deposits of strategic minerals and energy rival those of the African Continent and the Arab nations. The population is disciplined, semiskilled, and patriotic. Up to now, the [illegible]l hindrance has been bureaucratic inefficiencies [illegible] attempt to substitute for market forces. With computer-based systems directed at the management of information, the Soviets would have the potential for significant economic gains. Some Western observers fear the prospect of a USSR that successfully harnesses the power of computer technology to increase its productivity. Increasing the size of the Soviet economic pie will certainly make available to Soviet leaders more resources with which to threaten the interests of the West.

Fortunately, such a development is not likely in the near future. As in the Orwellian scenario, the Soviet bureaucracy simply does not trust information in the



Ekonomicheskaya Gazeta

What do we need new technology for, when the old technology is still working?

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hands of a great number of people. It always seems to boil down to who will be trusted with how much information. Furthermore, the USSR does not have the computer literate manpower base to create the national computer network needed. By the time such a manpower pool is developed, if it is, the measures of economic success may well have changed. Marshall Goldman suggests that the world may well place a higher value on computers and information rather than on the traditional criteria of the Industrial Revolution, such as tons of steel and coal. Thus, while Soviet leaders strive to optimize the processes of the past, the Western industrial nations have accomplished that and are focusing on new sources of wealth.[11] Others agree with

Goldman. Ambassador Francis Underhill says, "The modernized society creates wealth by the application of knowledge to the exploitation of inanimate sources; the traditional society depended on the labor of men and animals. While in the premodernized society, 70 to 80 percent of the population was engaged in agriculture, a modernized society needs less than 10 percent of the population on the land to produce the food it needs. These changes removed one of the major motives for war—the desire to preserve or acquire control over large numbers of people. . . . Control over, and responsibility for, large unskilled population is a serious liability."[12] Computer technology is key to the type of society envisioned by Underhill.

If the Soviets master the use of computers in a collective setting, their progress in this direction will be cautious and burdened by controls. Once again, identical technologies will be used in markedly different ways by fundamentally different political systems and cultures. However, we should bear in mind that computer technology has little in common with other examples of technology from the Industrial Revolution. It is a machine of the mind, not of the muscles. Thus, any potential this outcome has for upsetting international harmony rests in the nature of the computer as a unique machine.

The Wild Card

In addition to thoughts that high technology is changing the structure of the world economy, there is another powerful idea that may well impact on the Soviets' future. This is the concept of entropy. According to the second law of thermodynamics, matter and energy can only be changed in one direction, that is,

from the usable to the unusable, or from available to unavailable, or from ordered to disordered. This constant movement toward homogeneous disorder is an increase in entropy. Although for a long time after this discovery, it was believed that the learning process—the acquisition and understanding of information—created greater order and thus defied this law, this view is no longer held. The entropy law applies to the collection of information, which requires the expenditure of effort, as it does to all other areas of human endeavor.

Since the introduction of cybernetics and modern information theory, scientists have come to realize that the gathering, storing, and retrieving of information or knowledge requires the expenditure of energy. Thus, there is an entropy price that must be paid.[13] Though it is true that the computer is a great generator of information, thus adding to the entropy dilemma, it is also a great organizer and manipulator of information. In short, it may well prove to be the tool most capable of coping with the information explosion and its threatening state of disorder. Knowing what is available, where to find it, and how to retrieve the desired data is an enormous advantage. Clearly, the West is moving rapidly down the road of just such an application of the computer. There is little evidence that the USSR will do so.

These, then, are the principal points on the spectrum of possible outcomes to the Soviet computer dilemma, but I also hazard a more concrete prediction.

A Greater Gap

The Soviets will continue to improve in their use of computer technology but will not approach the level of application that this technology has seen in the West. Owing to all the factors discussed thus far, I conclude

that the most immediate consequence of the Soviet dilemma with computer technology and their prescription for dealing with it is the creation of an even greater disparity between the West and the USSR in the application of computer power. Indeed, the friction between the Soviet system and applied computer technology will contribute to the decline of the Soviet State as we know it.

Proliferation of the personal computer represents the clearest index of a society's commitment to and acceptance of computer technology. Herein lies the Soviets' real computer dilemma. Party rhetoric promoting widespread availability of computer hardware and software is only a cosmetic. People, many people, must be able and motivated to use the technology. As we have seen, at present the USSR abounds with disincentives for such behavior. Eventually computer education will create an increasing number of knowledgeable, computer literate workers. As these workers become more accustomed to using desktop computer technology, they will expect more and more from that technology. Even while the Soviet leadership members appreciate the need for such changes to increase manufacturing, planning, and administrative productivity and reduce waste, they are genuinely fearful about the prospect of rapid and uncontrolled information flow. To say the least, the party is in a quandary, and all the while computer technology is changing at a rapid pace.

Just as the computers of the 1980s bear no resemblance to their predecessors of the 1950s, so too the way computers are used today differs markedly from the approach of prior decades. This transition and its impact on the organization are best understood and described by the computer industry's most widely read author, James Martin, author of more than 25 major

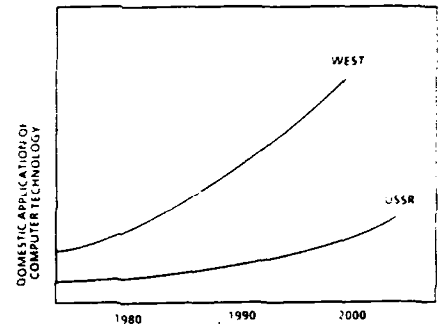

Figure 10

The widening gap between the West and the USSR.

works covering all aspects of the data processing industry:

End users [persons whose work is assisted by using computers] everywhere are becoming more aware of what computing can do for them. This awareness began to spread during the second half of the 1970s. Users began to see terminals obtaining data of different types. For the first time they had a window into data processing systems. They began to understand what information was stored. Their imagination began to tell them how *information from the computers could be useful to them.*

The change may be merely a technical one. The end user has better terminals, better data available for use, access to more remote computing resources, or minicomputers which serve user needs better.

Often, however, the change is more fundamental. The user department is drawn into the computing world instead of merely being a passive recipient of its service. The user department may have its own minicomputers or desk-top computers. Some users may learn to program. They may have intelligent terminals or peripheral computers with which they can generate their own reports from a corporate data base and answer questions not anticipated by the systems analysts in the central data processing group. They may have facilities to create their own computer applications without being professional programmers. They may learn to specify the data

they need for their job and be involved in creating it. User departments may become responsible for entering and maintaining the data they use. In one way or another they take an active part in data processing.[14]

Such is the data processing atmosphere in the West. And in nearly every sentence of Martin's comment is a concept that would cause Soviet leaders in the Politburo and Soviet bureaucrats everywhere to shudder. It is the modus operandi inherent in the use of modern computer technology that the Soviets find so threatening. Too many people must be involved, thereby diluting too much power. Consequently, for now the USSR seriously suboptimizes the use of computer-based systems via an implementation policy that stresses collective and controlled use. So while they may increase the number and caliber of computers in their inventory, they will not fully realize the benefits.

As we have noted before, no group or nation has a monopoly on the human thought process. If concepts and technology can be known, they can be understood and applied. Given the material wherewithal, technology can be replicated. But the real issue for the Soviets is what is to be done with such knowledge—how is it to be applied? Here is where Soviet cultural and political barriers enter the picture. To date these influences have acted to limit the Soviet use of computer technology. No real change is in sight.

The Twenty-First Century

No single force or event will account for the success or failure of any great nation. The synergy of various key forces is what matters. For the Soviets, the issue of computer technology is one powerful force in determining its potential success or failure—but only it competes

in that contest. How it copes with the potential of this force in the 1990s will determine its posture for entering the twenty-first century. Given the USSR's past record, the current trends in the field of computer technology, and the use of computer-based information systems, the emerging picture is one of a crack or chip in the curtain of Soviet tyranny caused by the natural workings of applied computer power. A chip that will over time continue to force change in the USSR.

Despite the rapid advancement in electronic computer technology in the first 40 years of existence, it seems clear that today's technology is merely on the threshold of even more profound transformations.[15] In the West, developments in the field of optics are so staggering that the term "Age of Light" has been suggested as a replacement for the current "Information Age." By combining the capabilities of lasers, fiber optics, computers, and telecommunications, engineers have been able to send thousands of pieces of information through microchips. Packets of light, bearing encoded pieces of information, have taken the place of streams of electrons that flow through today's microchips. This technology permits vast quantities of data to be transmitted faster, cheaper, and more accurately than by routing electrons through complex wire or semiconductor circuits, as we have done since the age of the telegraph and telephone. (The random and chaotic action of electrons routed through wire only approximates the speed of light.) A computer that uses photons (packets of light) instead of electrons when transmitting data and instructions will attain an operating speed nearer to the limiting speed of light. Owing to the greater capacity of photons to carry encoded data, such a computer would be 1,000 times as fast (performing

one trillion operations per second) as the most advanced of today's electronic supercomputers.[16] Such computers are now under development.

Current programs operating on the leading edge of computer design offer us a startling peek into the future. At least three major private corporations in the United States are currently working with the concept of neural networking molecular microprocessors in a deliberate attempt to mimic human thought processes. These projects have altered traditional computer architectures by arranging the components to replicate neurons interacting in the human brain. Such machines do not perform the traditional data processing tasks that we have come to identify with the word computer; rather, "clumps" of microprocessors are teaching themselves to read, see, and speak.[17] Knowledgeable engineers working on expert systems and artificial intelligence project fantastic images of the future. It is not necessary to accept all such claims, however, to realize that extremely significant programs are underway in the field of computer technology.

On the subject of predicted symbiosis between man and computer, we may consider the words of the Nobel Laureate, Professor of Computer Science and Psychology at Carnegie-Mellon University, Herbert Simon. In 1983 Simon noted, "All the mechanisms for human intelligence are present. Already machines [computers] can think just like people—in a limited sense. Man isn't unique in this respect."[18] Current developments seem to favor Simon's observations. That such progress is bringing and will bring about dramatic changes in the way we live, work, and think is a certainty. But here again, we should recall that the West is already very different from the East. Should we be alarmed at such prospects or their fulfillment?

To the extent that such developments promote differences in national attitudes and expectations, they may well be destabilizing to the world scene; we should be sensitive to that possibility. Change of this magnitude will most assuredly not be welcomed within the Soviet Union, a nation that has historically shown itself to be antipathetic to change. Should the West embrace computer technology to the point that man's intellectual powers are elevated to a superior capability we should expect a Soviet reaction which may range from a radical attempt to achieve parity to a turning inward or isolationist response. My analysis leads me to conclude that a Soviet resort to force to eliminate the threat is an unlikely reaction because the uncertainty of the outcome would be too great.

Rett Ludwikowski, Jiri Pehe, and others with first-hand experience in the ways of totalitarian rule predict that the rapid pace of technological change combined with fundamental inconsistencies and immoralities in the Soviet system are becoming their undoing. These writers place heavy emphasis on the problem of information control as a key factor in this process. But, in my conversations with those who study applied computer technology in the USSR, such as Richard Judy, William McHenry, and Carl Hammer, the issue of information control is not seen as being so paramount. Certainly, computers can be orchestrated to solve that problem.

One gets the distinct feeling that something is missing. Generally Western analysts underestimate the importance of power and partocracy—the ultimate values of the Communist system—as they are perceived and practiced by the Soviet elite. In their perception, such treasures must not be lost. If computer technology radically changes the West, so be it, the Politburo would say. Their conservative nature keeps them from rushing

headlong to keep pace. In the worst case, by the year 2088 the USSR may well be the present day equivalent of Albania, but the party and its political power would be intact. They know they can trust the West to respect their sovereignty and provide economic assistance to keep Western markets open and growing. All the more reason to move ahead slowly for the present.

In today's developed nations, we see more and more people gaining familiarity with computer technology, especially the inexpensive but capable personal computer. Mass exposure to this technology has naturally created a computer literate society in the West, a valuable human resource. To quote the words of countless contemporary writers who address this subject, "Users find the technology addictive." Rightfully viewed as a vast and skilled human resource peculiar to the developed countries of the West, a computer literate population begets the needs and solutions that continually fuel advancement in the computer industry. Yes, the West will differ even more markedly from the East in a hundred years.

Although East and West differ dramatically in numerous other ways, computer technology represents a unique difference. When used as a knowledge tool, it has the potential to aid man in the creation of ideas. As the speed and capability of computers increase, the combinations of assorted ideas that man may model and forecast also increase. This inevitably results in a race for knowledge, ideas, and new ways of combining and dealing with them. To the extent that the West dominates this process, it will project and determine the mainstream of world influence in the twenty-first century. In other words, computer technology and its applications will be a big chip in the poker game of East-West competition for influence in the Third World.

A Final Note

Any weekend do-it-yourself carpenter will attest to the importance of maintaining a level and straight orientation in the projects he undertakes. He has learned that his "eye" for checking the dimensions of his work is not always accurate and that it is best to augment his natural ability with straightedge and bubble. Soon this independent soul desires to build a shelf that exceeds the length of his tools. A professional contractor would have the proper tool but obtaining his services defeats the do-it-yourself ethic. Thus, the weekend carpenter learns to overcome his limitation by extending the reading provided by the level with a suitably long piece of lumber. An assumption is inherent in this approach—that the board is straight and level, thereby rendering the reading true. The purist recognizes the room for introducing error with this scheme, but the pragmatist appreciates the ability to avoid a catastrophic error, in this case, a noticeably crooked shelf. Such is our lot in studying the Soviets' computer dilemma.

We can see, and the Soviets readily admit, the USSR's backwardness in the application of computer technology. Indirectly we can gather data on the subject, but we lack the precise tools, more accurately, access to the right data, to measure the situation as exactly as we would like. Thus, many of the circumstances and implications of the situation are hidden from us. However, we do have enough knowledge to appreciate many of the reasons that contribute to the Soviet computer dilemma. Having negotiated the transition to a computerized society ourselves, we have been able to predict what is in store for the Soviets as they embark upon their transition. Understanding the nature of authoritarian regimes and modern computer technology, we have predicted the

likely outcomes for the USSR. The results may not be perfect, but they are sufficient to avoid catastrophic error in reacting to and establishing policies that touch on this subject.

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Index

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